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**SECOND AFRICAN CONFERENCE  
ON BILHARZIASIS  
(WHO/CCTA)**

**Lourenço Marques, Mozambique  
30 March - 8 April 1960**

**Report**

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WORLD HEALTH ORGANIZATION

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## SECOND AFRICAN CONFERENCE ON BILHARZIASIS

### Report

Perhaps some small degree of bilharzial infection has been characteristic of the people of Africa for an immeasurable time, but during the last half century or so it has become an increasingly prominent part of the African picture; it is an infection which development and progress have not only failed to control but have permitted or perhaps encouraged to increase far beyond its earlier prevalence. Now, in 1960, it is regarded as detracting seriously from health in some countries, as an infection of moderate significance to be considered in the company of many of equal importance in others, and as of minor or negligible importance in a few. Many uncertainties and doubts flow from this varied assessment. There may be many reasons for it, but it is notable that on the whole the countries which have progressed most in the utilization of their natural resources are perhaps the most convinced of the harm their people suffer, while others, less developed, have often been reluctant to devote their resources to the prevention of something which has seemed a not overburdensome part of the natural balance between man and his surroundings.

Whether a part of a balance or not, it is an infection which characteristically causes gross pathological changes in several parts of the body. The World Health Organization has consistently tried to give technical aid to those countries which look on it with concern, and has organized many surveys, arranged visits by consultants and a bilharziasis advisory team, provided training and fellowships, promoted research and organized technical discussions in expert committees, study groups and conferences. These have provided substantial contributions to knowledge and encouragement to the organizers of and participants in individual schemes of control or research. However, the observations made have tended rather to accentuate the general significance of the infection and to stress its great prevalence than to stimulate any comparable sense of urgency in its control. Indeed, the relative speeds of progress in general development and in bilharziasis control might justify a pessimistic appraisal of the risk of more development being matched by more, and more significant, bilharziasis.

With this in mind, the World Health Organization and the Commission for Technical Co-operation in Africa South of the Sahara (CCTA) jointly convened this Second African Conference on Bilharziasis in the African Region, attended by 28 technical representatives of the following countries in the African Region: Angola, Belgian Congo, Cameroun, Central African Republic, Republic of Chad, Republic of the Congo, Ethiopia, Kenya, Malagasy Republic, Mali Federation, Mozambique, Republic of Niger,

Portuguese Guinea, Federation of Rhodesia and Nyasaland, Tanganyika, Uganda, Union of South Africa, and Republic of the Upper Volta ; by three observers from international agencies ; and by consultants and staff from WHO and CCTA.<sup>1</sup>

Broadly, its terms of reference were to examine the bilharziasis situation in Africa and the potentialities for control, and to make recommendations. Its proceedings were active and notable both for the general participation of all its members and for the ease with which they achieved agreement on points at which disagreement has sometimes in the past prevented progress.

Bilharzial infection is very widely prevalent in Africa and is increased by many of the processes of material development. It is always gravely significant to the individual, owing to the permanent damage which it commonly inflicts, and by which it should be judged rather than by its transient effects. Present knowledge is such that the disease can be prevented in any localized circumstances. Though much research is needed, the pressing problems of control are related rather to the deployment of skills, materials and work than to uncertainty of methods. Selective control of snails in places where man incurs the greatest risk of infection may greatly lessen risks. Co-operation between epidemiologists and engineers can eliminate the risks involved in expanding irrigation systems.

The techniques of killing or otherwise controlling snails in most environments are well established, though they are often unused.

The Conference believed that these techniques and aspects of knowledge can and should be brought together in many pilot projects, each representative of the district or part of the country in which it is located, with the object of testing and modifying them and putting them to wider use. Although not considering the problem in terms of eradication, the Conference believed that a halt can be called to the progress of the disease, that this may be followed by a recession in the number of cases, and that eradication might finally come.

## 1. ASSESSMENT OF THE MEDICAL AND PUBLIC HEALTH IMPORTANCE OF BILHARZIASIS

### 1.1 Additional information on the distribution, prevalence and hosts of the disease

#### 1.1.1 *Infection in man*

The widespread dissemination of bilharziasis in Africa has been documented in the report of a previous conference.<sup>2</sup> It was not possible at

<sup>1</sup> Throughout this report, countries in the African Region are referred to by the designations in use at the time of the Conference (March-April 1960).

<sup>2</sup> African Conference on Bilharziasis (1957) *Wld Hlth Org. techn. Rep. Ser.*, 139

that time to map the intensity of local prevalence, though this was known to be very severe in many parts of the continent. There has been little addition to knowledge of either distribution or prevalence since that time. There have been reports of a previously unrelated large focus of *Schistosoma haematobium* in northern Madagascar, and of another in the Republic of the Congo, but there is no apparent need otherwise to modify the previous statement of distribution. The numerous statements of the degree of local prevalence continue to indicate that bilharziasis is one of the common infections of Africa, but they are still not sufficiently detailed to justify the preparation of a new map or schedule. Information on the prevalence of infection in a country is a very important prerequisite for the formulation of policy on control and for planning control methods. The Conference therefore stressed the importance of studying the prevalence of the disease, and suggested that as information was collected and brought together for major areas, or for areas previously thought free, it should be forwarded to WHO for collation with other similar information and for distribution to those concerned.

There has been some additional information since the previous conference<sup>1</sup> on the occurrence in man of schistosomes of the *S. bovis* group. Infection is becoming increasingly common in some irrigated areas where cattle are numerous; where in some areas they come into close contact with man or use and foul the same water, as many as 40% of the human population have been found infected. When these worms invade man they appear to show no preference as between the urinary or intestinal tracts, though the bladder is affected in less than 10% of cattle infections. They have been successfully transmitted from man to several species of rodent and, though without the production of eggs, to a calf and a sheep.

Worms of the *S. bovis* group have been found in man in the Union of South Africa, in Mozambique, and once in Uganda, and *S. rodhaini* has been recorded in man in the Belgian Congo. Their importance lies in the fact that both man and his domestic animals are susceptible, that high infection rates have been found in some places, that it has been suggested that a hybrid form between *S. mattheei* and *S. haematobium* has been produced and can propagate, and that whether or not this is the case a common zoonosis could become established in some places. This risk could probably be avoided by preventing bathing and the washing of clothes at or near cattle-watering places.

#### 1.1.2 *Schistosomes of man in other definitive hosts*

The dog-faced baboon, *Papio doguera*, has been found to be infected, commonly in some places, with *S. mansoni*, and the significance of this

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<sup>1</sup> African Conference on Bilharziasis (1957) *Wld Hlth Org. techn. Rep. Ser.*, 139

finding has still to be fully evaluated, though there is as yet no reason to believe that it will be great.

The rodents *Mastomys natalensis*, *Otomys tugelensis* and *Lemniscomys griselda* have been found naturally infected with worms of the *S. bovis* group, and the two former with *S. mansoni* in the Transvaal. Infections were light, but were at least temporarily numerous in one African township through which a canal runs, 20%-25% of rodents being found infected. This rate dropped after continuous trapping, until it became very unusual to find infections. Infections have been recorded elsewhere, though never in large numbers. It is probable that the susceptibility of rodents to schistosomes which can infect man constitutes a significant risk to public health in quite exceptional circumstances only, especially as the short life-span of the rodent would seem to make maintenance of infection dependent on reintroduction from man or cattle. It has been shown that miracidia from worms in rodents can infect snails, even by contamination arising during decomposition of dead animals, but the cycle has not so far been completed experimentally by return of the infection to rodents.

### 1.2 Morbidity and mortality attributable to schistosome infection

There has been in the past a wide divergence of views on the significance to the community of schistosome infections and, in consequence, of the priority which they should be accorded in public health programmes. Much disagreement has perhaps been due to the focusing of attention on quite different aspects of a most complicated condition, in which there may be need to take account of different species, and perhaps strains, of infecting worms, of widely varying loads of infection, of the importance of different aspects of the disease and particularly of the relative importance of the acute and late stages of it.

Among these various sources of complication, the Conference considered particularly the relative significance of different phases of the disease. Many assessments have in the past been based on an appreciation of the significance of the clinical syndromes, which are commonly recorded in dispensary or clinic records as "bilharziasis" or "schistosomiasis" and which include almost solely the acute stages of the disease. It thought that concentration on this aspect of the disease had perhaps diverted attention from what is often a very much more significant aspect—namely, the more advanced irreversible stages and the sequelae, which might appear long after the initial infections and perhaps when apparent signs of active infection were diminishing, and the importance of which is usually brought to attention only with the establishment of a full autopsy mechanism with associated studies of morbid anatomy.

Assessment of morbidity is, it must be recognized, much the most difficult in acute temporary conditions, unless characterized by a readily

definable period of incapacitation for work. An analysis was prepared of the different aspects of infection, to consider which should be brought into account in this connexion. The pathological effects of infection with all species are fundamentally similar, though they differ in detail and in degree, and may be conveniently described in three phases.

### 1.2.1 *Stage of invasion*

The intensity of infection during the invasive stage may declare itself in ways which at present are not recognized as specifically due to bilharziasis. There is more than suggestive evidence, certainly from experimental work, that the lungs are acutely injured by the schistosomulae, producing what would at first sight appear to be, and is not easy to differentiate from, acute pneumonitis. The morbidity from this pneumonic lesion therefore has to be assessed.

### 1.2.2 *Established infection*

The latent period after the invasive stage allows for adaptive processes to occur. Very little is known of the effect on the structural and functional integrity of tissues, veins and capillaries, which may harbour large numbers of worms. Death of these worms, occurring spontaneously or after specific treatment, may be followed by dislodgement and the formation of emboli. The mechanical effects of these emboli alone, as in the case of emboli formed in other ways, may lead to tissue damage through interference with the blood supply to the organs, and there is sufficient evidence from experimental and human pathology to show that the dead worm can induce an intense tissue reaction which is eventually followed by the formation of granulomata and scar tissue. In the case of the liver, death of a large number of worms in the portal radical can lead to acute hepatitis. Much of the local reaction during this stage is reversible by treatment. Clinical manifestations may be acute and tend to be localized; they are usually classed as "schistosomiasis" or "bilharziasis" in hospital records.

### 1.2.3 *Irreversible effects and sequelae*

These are numerous and are principally attributable to intense reaction, of a nature dependent on the tissue concerned, around eggs which may be deposited in any tissues of the body and in great numbers. The diffusion of eggs in the body has been noted in previous works, and an idea of the extreme densities achieved can be gained from Table 1.

Reaction in the urinary tract usually produces a cystitis with formation of fibrous tissue, granulomata or polyps, of sandy patches or massive calcification, often complicated by secondary infection. This process, once initiated, proceeds relentlessly for years owing to the continued deposition

**TABLE 1. NUMBER OF SCHISTOSOMA EGGS FOUND BY DIGESTION OF 20 g OF CERTAIN ORGANS \***

Organs examined	Total examined	With <i>S. haematobium</i>			With <i>S. mansoni</i>	
		Positive	Number of eggs		Positive	Number of eggs
			From	To		
Bladder	39	32	40	in-numerable	1	20
Liver	66	22	20	3400	2	400
Lung	34	16	20	4600	—	—
Pancreas	334	10	160	2200	—	—

\* Data collected from egg counts done in organs obtained in routine unselected autopsies performed daily since 28 February 1960 in Lourenço Marques.

of eggs, with effects on the bladder structure and the health of the individual which may be devastating. There is also an almost invariable distortion of the ureter and pelvis of the kidney, very commonly leading to some degree of hydronephrosis, which is found in as many as one in four of infected adults. This is often associated with infection, and may be the cause, in very marked cases, of impairment of renal function.

There is also some association between intensity of bilharzial infection and the occurrence of squamous carcinoma of the bladder, the exact form of which is now being actively studied in Egypt and Lourenço Marques, where data covering many years are available.

In the liver the mass liberation of eggs into the intrahepatic radicles leads to local circulatory obstruction and to acute focal necrosis, the severity of which depends on the intensity of egg deposition, but which may even terminate fatally. In such cases diagnosis may be difficult without very careful histological examination. With more usual intensities of egg deposition, widely dispersed throughout the liver, the general nature of reaction is very similar to that in the bladder, with liberal formation of fibrous tissue, except that instead of polyp formation the portal tracts are enlarged with consequent mechanical interference with the flow of both blood and bile. Either mass liberation of eggs or the more usual intensities of egg deposition may cause some degree of necrosis, particularly on the edge of the lobules, with the stimulation of an intense fibrous tissue reaction culminating in a classical pipe-stem cirrhosis.

Particular attention has been paid to the influence of *S. mansoni* in causing hepatic cirrhosis, and little to that of *S. haematobium*, which is probably, however, very important. Laennec's cirrhosis is very frequent in Lourenço Marques, where there is little *S. mansoni* infection and where *S. haematobium* is often found in the liver, a causal connexion being strongly suspected. Most of the infection is acquired in childhood, cirrhosis

very commonly develops in adolescence and constitutes a deprivation of function and impairment of health throughout all adult life.

Reaction in the liver and the spleen is marked by enlargement and is probably frequent. The causal relationship cannot always be established. Malaria may have a similar effect, though common helminth infections do not. It is recommended that special studies be made to determine the association of bilharziasis and malaria in the hepatosplenomegaly syndrome.

As in the case of the bladder, there is a possibility that cancer of the liver may be causally associated with bilharzial infection. The Conference, reviewed the remarkable prevalence of one form of liver cancer in Lourenço Marques, an area heavily infected with *S. haematobium*, where the annual incidence of such cancer in males amounts to 214 cases per 100 000 population aged 40-50 years. The association is not proven, but the known facts are very suggestive of it and fully justify further study.

The reaction of the liver to bilharzial invasion is exaggerated by, or exaggerates the effects of, malnutrition, alcoholism, infective hepatitis, and intercurrent infections such as pneumonia or tuberculosis. The degree of these indirect effects cannot readily be assessed. Cirrhotic and cancerous conditions of the liver of cattle in endemic bilharziasis areas have been reported, and in experimental bilharziasis a high percentage of liver cancer results following infection of *Mastomys natalensis* with *S. mansoni*.

In *S. haematobium* infection, the lung may often be affected in all phases of infection. The intense reaction following cercarial invasion has been noted. Mature worms may invade the lung and, though this is not generally known, eggs may sometimes be recognized in the sputum. The deposition of eggs leads, as in other organs, to destruction of physiologically active tissue, granulomata, and proliferation of fibrous tissue. A diffuse invasion therefore leads to extensive pulmonary fibrosis. The resultant pulmonary hypertension, sometimes with cardiac failure, has been well established, though its frequency, which deserves further study, has not been sufficiently estimated.

Changes in the alimentary system are basically the same as in other tissues, often with very marked granuloma formation and local replacement of functioning tissue by fibrous tissue. The direct effects are increased by the consequences of irritation of the autonomic nervous system, following either direct invasion of ganglia or the influence of local inflammatory processes. This sometimes profoundly affects the clinical picture by exaggeration of local reaction.

Finally, in places where bilharzial infection occurs in early life, the growth and differentiation of tissue is sometimes profoundly modified, with the production of stunting, or even dwarfing, and of endocrine disturbances.

The usual clinical picture, which is described above, may be modified in degree by several factors. As in any helminth infection, the load of

worm carried may vary within wide limits and it is presumable that clinical manifestations vary in at least rough accordance. Concurrent infections and deficiencies of nutrition may affect the picture and sometimes confuse it, and it is possible that the pathogenicity of strains of helminth varies, though the degree of such variation is not known.

The Conference hoped that research into the influence of these or other modifying factors would be encouraged.

#### 1.2.4 *Conclusions on morbidity*

The main public health importance of the disease lies in the occurrence of the irreversible phenomena and sequelae, which always seriously detract from the ability and health of the individual and, in addition, expose him to considerable specific risks. Attention has not been focused on them in many countries because they are not at the time necessarily associated in the minds of the public, and often not in the minds of the medical profession, with the schistosomal infection which is their main cause and because by their chronic nature they tend to become accepted without gross complaint, although in total they amount to a considerable impairment of health.

An assessment of the morbidity or ill-effects of any schistosome infection which is based on the occurrence of acute transient effects or on days in hospital attributable to them is quite inadequate, because it inevitably ignores the importance of these widespread and irreversible pathological changes. The assessment should include transient effects, but should primarily be based on the occurrence of the irreversible changes and their influence on the total biology of the population. Organic damage of the type described, with its resultant impairment of function and exposure to specific risks, lessens both the value and the expectation of life, and, if it occurs in many people, detracts seriously from the total health of the community.

### 1.3 Principles and methods for quantitative assessments of morbidity and disability

#### 1.3.1 *Indices of prevalence*

In the past quantitative assessments have usually been based on appreciation of the existence and intensity of infection in particular individuals and comparisons of these with the degree of disablement from which they were found to suffer. This method ignores the distinction between the effects of immediate reaction to invasion and the irreversible effects and sequelae which may occur after long intervals. It is necessary to evaluate the prevalence and intensity of schistosomal infection in a community, for which purpose all standard procedures, including the measurement of infection rates by examination of urines and stools and by serological tests, should

be utilized. These rates, however, are to be considered as indices of the prevalence of the infection within the community concerned rather than as direct guides to the discovery of the particular individuals in whom pathological effects might be discovered. If an assessment is to be made of the morbidity and mortality attributable to infection, it can only be by an evaluation of the relative frequencies of different types of disablement in communities with different degrees of prevalence of schistosome infection. Such an evaluation can be made by a survey of the whole or of a carefully arranged sample of the population or, in exceptional circumstances, by systematic autopsy studies. It is therefore essential that studies of this subject should be carried out in the areas where transmission actually occurs in order that findings may be related to the local prevalence of infection.

The Conference considered that every effort should be made to standardize methods of measuring these indices in order to secure comparability of findings, and so that these findings could be used as reliable indices of the total infection rate, even though they may not demonstrate every individual who is infected.

Much reliance for field survey procedures will necessarily be placed on the detection of eggs in urine or stools, current techniques for which vary in accuracy and reliability. The Conference supported the recommendation of the previous conference<sup>1</sup> that sedimentation techniques, such as the MIFC (Merthiolate, iodine, formaldehyde concentration), should be used for examination of stools and tissues, and considers it desirable that some quantitative measure of the numbers of eggs should be made wherever practicable.

In this connexion it noted with appreciation the effort which WHO is now making to secure an adequate standardization of serological techniques, particularly the skin sensitivity test, and it hoped for the further encouragement of work in this and allied subjects. It received a report on the use of Coons' fluorescent antibody technique in the serological study of bilharziasis, and considered that this approach merited support because it gives hopes of a more quantitative and precise understanding of human reaction and immunity to infection.

In individual cases or for more accurate assessment of the true incidence of bilharziasis in a population one must turn to rectal biopsies, which are possible in hospitals, though they are not recommended for field surveys. However, under careful control on relatively small samples one can establish a relative ratio of total cases as revealed by rectal biopsies to cases revealed by sedimentation methods. In any given area such a ratio should be sufficient for practical and realistic evaluation of the level of bilharziasis in that area.

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<sup>1</sup> African Conference on Bilharziasis (1957) *Wld Hlth Org. techn. Rep. Ser.*, 139

If additional evidence is needed and facilities cannot be provided for rectal biopsies, rectal scrapings obtained with a curette can furnish a simple alternative with almost equivalent accuracy. To obtain complete accuracy and to assess long-range effects of bilharziasis one must use either surgical procedures or autopsies on a large series of unselected cases.

The relation which the results of these field methods bear to the total infection rates and to the intensity of infection is not sufficiently understood and deserves further study. The Conference considered it advisable that research to this end should be encouraged, and envisaged it taking the form of careful research studies, in hospitals or other appropriate centres, of the relative reliability and sensitivity of different techniques.

### 1.3.2 *Surveys of morbidity in relation to prevalence*

Enough is known about the frequency of irreversible effects and sequelae of infections to justify the assertion that control of transmission should not be dependent on any local inquiry into this subject. It is, however, desirable to expand knowledge of the subject and to measure more precisely the frequency with which these effects occur and their relationship to such matters as the local intensity of infection. There would be considerable difficulties in the organization of studies to this end, which would have to be closely related to natural population groups, such as village communities, and would necessarily include parallel measurement of indices of prevalence and intensity of infection, and of pathological changes and morbidity, in one and the same community. Furthermore, since the exact relationship of individual pathological changes to a bilharzial origin might be difficult to determine, even when the general relationship of such changes to this cause is necessarily established, it would be necessary to carry out research studies of this nature in a number of localities, which are otherwise similar, selected for the range of prevalence of infection which they represent and in one where infection is absent.

Studies would involve a quantitative assessment of the prevalence of disabilities, many of which are not normally recorded as attributable to bilharziasis, and of the extent to which they are actually attributable to it, in communities subject exclusively to *S. haematobium* or *S. mansoni* infection, with control examinations in a community free from infection. This involves the development of elaborate diagnostic facilities and skills in different hospitals for various periods to make sample surveys of the prevalent causes of attendance in clinics and in the wards, with a consistent effort to attribute chronic conditions of the genito-urinary, circulatory and alimentary systems to their basic cause. These elaborate sample surveys would be carried out in parallel with a more traditional type of survey, covering the entire population and its environment, and including a measurement of the local prevalence of infection and if possible of the amount

of invalidism revealed by house-to-house visits. It would not be necessary to make a full epidemiological study of infection in each case, though the series of surveys would best be associated with such a study in one area.

Many normally accepted centres of high-standard diagnosis would be precluded from being of much utility by this definition, and it might be necessary to provide the diagnostic facilities and skills at rural hospitals which are normally less favoured. The period of survey involved in each area would be a matter of six months or so, and the series of surveys might last three years. A team mechanism has considerable advantages for this purpose and one major disadvantage which would need to be overcome if it were to be used. It is not likely that it would be possible to persuade people of sufficient quality and position in the field of clinical medicine and pathology to devote themselves exclusively to this subject for the length of time required, during which they might lose contact with people and with advancing thought in a rapidly changing professional world. Both a clinician and a pathologist would be needed in any team and though neither need have the experience which would qualify them as authorities, both should have a very high standard of critical ability within their professional field. Such people are now being trained in or attracted to scientific medicine in Africa, where they may work in professorial units of the medical schools and at some other main clinical centres. It would be possible to operate a team mechanism which brought them into closer contact with rural areas and so made it possible to base surveys on them. There is reason to believe that under certain conditions the process would be greatly welcomed as an extension of research processes.

Such a team should attempt accurate diagnosis of prime causes of chronic illnesses and conditions thought possibly connected with schistosome infection, and a quantitative assessment of their frequency in relation to clinic and hospital attendances. A local survey of the prevalence of infection in the population served by the centre, of the degree of its exposure to schistosomes and of the species of infection is also needed. The hospital or clinic attendances should also be related to the size of the population, and an effort should be made to secure a record of all deaths occurring within a fixed period, with as much information as possible as to cause.

### 1.3.3 *Other related studies of morbidity*

The type of survey advised should go a long way to measuring the morbidity associated with different intensities of bilharzial infection, but for completeness it needs elaboration in several ways : (1) estimation of the effect during infancy and early childhood, with special attention to the load of infection and the state of infection or immunity in the mother ; (2) further studies of the relationship of infection to carcinoma of the

bladder, carcinoma of the liver, and other grave end-results ; and (3) studies of the way in which pathological effects are influenced by different epidemiological pictures, such as the perennial, seasonal, or more occasional massive transmission.

Studies on these lines are under way in Mozambique and in Tables 2-5 are shown some of the results obtained, which concur with similar studies undertaken in Southern Rhodesia and the Union of South Africa.

**TABLE 2. TYPES OF LIVER CIRRHOSIS IN AFRICANS OF PORTUGUESE EAST AFRICA**

	With <i>Schistosoma</i> eggs in liver	" Pipe-stem " without eggs in liver	With fat	Without fat	Total cases
Type 1	65	5	20	69	159
Type 2	5	1	4	45	55
Type 5	0	0	1	3	4
Type 6	0	0	2	2	4
Total	70	6	27	119	222

**TABLE 3. DISTRIBUTION BY AGE AND SEX OF 266 CASES OF LIVER CIRRHOSIS IN AFRICANS OF PORTUGUESE EAST AFRICA**

Age-group (years)	Total number of autopsies		Total number of cirrhoses		Percentage of cirrhosis in all autopsies at each age-group	
	M	F	M	F	M	F
1- 9	231	177	4	9	1.7	5.0
10-19	247	62	40	7	16.2	11.3
20-29	348	160	32	18	9.2	11.2
30-39	347	119	34	15	9.8	12.6
40-49	394	119	37	10	9.4	8.4
50-59	220	96	23	8	10.4	8.3
60-69	128	103	12	9	9.3	8.7
70-79	99	82	2	3	2.0	3.6
Not stated	37	26	3	0	8.1	0.0
Total	2 051	944	187	79	9.1	8.3

**TABLE 4. FREQUENCY OF SCHISTOSOMAL INFESTATION OF THE BLADDER IN PORTUGUESE EAST AFRICA, AS ESTABLISHED HISTOLOGICALLY IN 478 CONSECUTIVE AUTOPSIES (322 MALES AND 156 FEMALES) DISTRIBUTED ACCORDING TO AGE AND SEX**

Age-group (years) and sex	Number of cases	Presence of ova	
		Number of cases	%
0-9 M F	61	8	13.1
	37	7	18.9
10-19 M F	28	17	60.7
	6	3	50.0
20-29 M F	59	41	69.5
	21	15	71.4
30-39 M F	56	46	82.1
	25	17	68.0
40-49 M F	50	36	72.0
	25	12	48.0
50-59 M F	35	21	60.0
	19	11	57.9
60 and over M F	33	20	60.6
	23	13	56.5

**TABLE 5. AGE DISTRIBUTION OF CANCER OF THE BLADDER IN LOURENÇO MARQUES \***

Age-group (years)	Percentage of cases
Below 15	0
15-29	4
30-39	24
40-49	33
50-59	17
60-69	17
70 and over	4
Unknown age	1

\* From histological examination of 100 cases of bladder cancer at the Miguel Bombarda Hospital, Lourenço Marques.

#### 1.4 Economic importance of the disease

The importance of bilharzial infections in Africa is thought to lie in the morbidity and mortality they cause, but it is desirable also to recognize and so far as possible evaluate their economic effects, as information on

this subject would be helpful to public health administrators in obtaining economic support for extensive control programmes.

Substantial difficulty in accurate appraisal of economic losses in an area where there is not full employment, where medical and health services are not currently available to the entire population, where intercurrent disease frequently complicates the situation, and where lowered productivity is difficult to recognize and almost impossible to evaluate greatly complicates an undertaking of this sort. It can only properly be carried out with the very close co-operation of, on the one hand, physicians able to recognize the disabilities due to infection and the loss of working potential attributable to them and, on the other hand, economists and sociologists able to analyse the impact of this loss on the productivity and welfare of the community.

Such a long-range study should not postpone attack upon the critical problem of bilharzial infection in Africa.

A study of this sort should take account of: (1) the loss of potential productive capacity in all groups of the population, together with a realistic assessment of the loss of potential attributable to chronic incapacity, semi-invalidism, and death; (2) the direct costs attributable to the disease in terms of hospital beds, treatment facilities and control measures; and (3) special costs, including such matters as inability to deploy the manpower necessary to take advantage of opportunities of irrigation or other forms of development.

The Conference noted some possible techniques for the execution of such surveys and considered that the form which has been developed in a Philippine context<sup>1</sup> deserves study and adaptation to African conditions and to the difference between the clinical effects of *S. haematobium* and *S. mansoni* from those of *S. japonicum*. The method has the virtue that it includes a survey of an entire population and an assessment of the amount of disability over some prolonged period in each individual, but depends on the preliminary establishment and application to the individual of a "clinical gradient", which it may be very difficult to define with sufficient realism and accuracy to pinpoint all disability due to bilharziasis without either minimizing or exaggerating it. For these reasons the technique originally developed should be regarded, so far as African conditions are concerned, as an important research study rather than as a technique capable of routine application.

It is also desirable to explore the possibility of studying the economic evolution of contrasting communities—namely, those which are heavily infected and those which have been freed from infection by control measures.

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<sup>1</sup> Pesigan, T. P. et al. (1958) *Bull. Wld Hlth Org.*, **18**, 345, 481; **19**, 223

## 2. SNAIL CONTROL BY CHEMICAL MEANS

Although the Conference recognized the part played in bilharziasis control by health education, sanitation and mass treatment campaigns, it was of the opinion that control by mollusciciding offered the most efficient single method of control.

### 2.1 Review of present and prior employment of molluscicides and of results obtained

The currently employed molluscicides and those still in the experimental stage were reviewed with respect to their availability, cost, toxicity to different animals and plant life and other essential properties under different conditions. A comparison of three compounds is given in Table 6.

#### 2.1.1 *Copper sulfate*

In many parts of Africa, copper sulfate is readily available at relatively low cost. While it is toxic to snails, it has no appreciable toxicity to mammals and is less toxic to fish than are the other available molluscicides. Under certain circumstances, e.g., in very soft clear waters, it is more efficient than some other molluscicides.

As copper sulfate does not generally kill snail eggs in natural waters, the necessity of giving a minimum of two applications in any one complete treatment programme makes it more expensive than sodium pentachlorophenate. It is rapidly precipitated in hard water with a high pH but in hard water with a low pH it will remain in suspension and still be lethal to snails. It is usually necessary to undertake weed clearance before application of the chemical and there is a possibility of a build-up of the copper to toxic levels in water or soil under continuous treatment. There is little cercaricidal effect. As it is highly corrosive, a careful choice must be made of the equipment used. As high concentrations are usually required (30 p.p.m.), large quantities may have to be transported.

It has been reported that the continuous application of 0.125 p.p.m. of copper sulfate for five years is very effective in controlling the snail populations. This report has not been confirmed by other studies.

#### 2.1.2 *Pentachlorophenate*

Sodium and copper salts have been used. The advantages of sodium pentachlorophenate as a molluscicide are that it is cheap and easy to handle and, in the majority of instances, there is no necessity to clear vegetation before applying it. However, in some places in the Belgian Congo it was found necessary to remove vegetation in order to kill snails. In

TABLE 6. COMPARISON OF THREE PRINCIPAL MOLLUSCIDES

Molluscicide	Copper sulfate	Sodium pentachlorophenate	Bayer 73 (ethanolamine salt)
Form	Crystalline	Salt briquettes, pellets, powder	Salt
Water solubility	Soluble	Soluble	Soluble
Lethal dose (average efficacy in field)	20-30 p.p.m.	5-10 p.p.m.	0.3-0.5 p.p.m.
Duration of contact	—	8 hours for 10 p.p.m.	Insufficient data
Action on snail eggs	Nil	Effective	Effective
Action on cercariae	Nil	Effective	Effective
Advisability of pre-weeding	Generally advisable	Generally unnecessary	Generally unnecessary
Effect of pH on activity of molluscicide	Decreases with increase in alkalinity	Little known effect	Optimum pH: 7-10
Effect of hardness of water	Dependent on pH	Slight reduction	Insufficient data
Effect of turbidity on activity of molluscicide	Decreases	Increases	Insufficient data
Effect of electrolyte concentration	—	—	Favoured by high salt content
Effect of sunlight	Nil	Reduces efficacy	Probable reduction after 24 hours
Toxicity to fish at applied dosage	High	Very high	Very high
Toxicity to man and domestic animals at applied dosage	Nil	Nil	Nil

flowing waters this compound is usually applied at a concentration of 10 p.p.m. for eight hours. In static waters effective results have been obtained at concentrations of 5 p.p.m. It can be easily applied in irrigation canals where the amount of water flowing can be calculated and where a snail kill can be obtained for very long distances from the application point. It has a further advantage in that it kills cercariae and snail eggs in the same concentration as is used to kill snails. It does, however, have the serious disadvantage that it is destroyed by sunlight. In many situations this disadvantage can be overcome by applying the compound late in the afternoon. Its molluscicidal effect is reduced in hard waters and at the same time there is a more complete and rapid breakdown in hard waters.

It is very toxic to fish and it has been reported that its irritant effect on snails may cause them to leave their habitat. Although it may be disagreeable to use owing to its very irritating effect on mucous membranes, when it is used in molluscicidal applications at the concentrations recommended it is not toxic to humans or domestic animals. It is non-corrosive and may be used with a wide variety of mechanical equipment.

Copper pentachlorophenate is a highly effective molluscicide. Since it is insoluble in water it may be applied in the field by independently dispensing copper sulfate with sodium pentachlorophenate. This technique has been used successfully in Venezuela.

It is non-irritant to snails and may have a longer residual effect than either copper sulfate or sodium pentachlorophenate.

As pentachlorophenate is sometimes used as an insecticide and herbicide, it is produced in large quantities and its manufacturing cost is comparatively low.

### 2.1.3 Bayer 73

In a few places in Africa, this new molluscicide (5-chloro-salicylic acid (2-chloro-4-nitro) anilide) has been tested both in the laboratory and in field trials, and the following conclusions may be drawn from the available data.

It is toxic to African intermediate hosts of *Schistosoma* and their eggs at concentrations as low as 0.3 p.p.m. Under the conditions of the trials carried out, it appeared to have equal efficacy in the laboratory and in the field. Ponds treated with the compound at concentrations of 0.3 p.p.m. remained free of snails for a period of at least eight weeks. Laboratory tests show that snails are not irritated by Bayer 73 and, therefore, are not stimulated to leave treated water and so escape lethal concentrations. High water temperatures appeared to enhance the activity of the compound and its efficacy is further increased in alkaline waters to a maximum of pH 9 and in water high in total dissolved solids. No scorching effect on higher plant life has been noted (though algae may suffer) even at water tempera-

tures of 33.9°C with a concentration of 1.5 p.p.m., though slight wilting of vegetation has been noted ; such vegetation quickly recovered.

Applied concentrations of Bayer 73 were reduced to trace amounts by the ultraviolet irradiation of strong sunlight and there is evidence that applied concentrations are further reduced owing to adsorption by aquatic vegetation.

It has been shown that schistosome cercariae are killed within five minutes by concentrations of Bayer 73 of 0.2 p.p.m., and it is toxic to fish at a concentration of 0.3 p.p.m. In mice the product has very little toxicity on single or repeated oral administration. They tolerated single oral doses of 2 g/kg, and rats tolerated doses of 5 g/kg. Bayer 73 and its ethanalamine salt have so little toxicity for warm-blooded organisms that no harm to humans or livestock is to be expected. The compound is easily handled and is not irritative to man. The ethanalamine salt is soluble in water, non-corrosive, and can be applied using simple apparatus of low cost.

This compound is effective against intermediate hosts and their eggs at concentrations much lower than are necessary using other available molluscicides. At present, the cost of this chemical is not known, but it is hoped that for molluscicide application it will not be greater than that of other currently used compounds.

#### 2.1.4 *Aqualin*

Acrolein is the active ingredient of this herbicide, which is used in clearing submerged aquatic vegetation from irrigation canals. Field and laboratory tests in California and Puerto Rico show that it is highly toxic to snails and their eggs. The compound is volatile and is therefore not injurious to crops. Since caution must be used in handling it, it should be used only by specially trained personnel. It would be practical only in areas where it could be used for combined weed and snail control in canals.

#### 2.1.5 *Molluscicide I.C.I. 24223*

Results with this new molluscicide indicate that it is effective in still waters at a dosage of 0.4 p.p.m., but in running water at 0.27 p.p.m. applied for three hours there has been no effect on the snail population.

At concentrations used to kill snails, the chemical is toxic to fish but non-toxic to man.

### 2.2 **The extent of mollusciciding programmes in African territories**

The extent of mollusciciding programmes in Africa south of the Sahara at the present time is probably directly related to the relative importance attached by the responsible governments of the different territories to schistosome infection.

It is a regrettable fact that large-scale mollusciciding takes place in relatively few countries and is restricted in the others to localized irrigation schemes or to experimental use.

Copper sulfate and pentachlorophenate have been effectively used as molluscicides for a number of years. New compounds also appear to be very promising. It is hoped that governments will in future find it possible to carry out more widespread mollusciciding programmes.

In Southern Rhodesia, copper sulfate has been used for several years and with considerable success in some places characterized by having soft waters in which the compound is particularly effective. In other areas it has been replaced by sodium pentachlorophenate. In Southern Rhodesia all water sources in an area of 6 000 000 acres (about 25 000 km<sup>2</sup>) are being treated with either copper sulfate or sodium pentachlorophenate. The area is divided into "intensive conservation areas" of approximately 250 000 acres (about 1000 km<sup>2</sup>) in extent; in European-settled areas control is in the hands of the farmers, and in African areas in the hands of the Government. It has been found that each area requires methods applicable particularly to it; and, further, that reinfestation takes place unless application of molluscicides is made on a large scale such as that of the intensive conservation areas. Following the successful application of molluscicides, snail surveillance is instituted and if snails are found the focus is treated.

Snail control in reservoirs has given difficulty in certain areas. In some places this may have been due to an insufficient amount of compound (NaPCP) being applied. Diffusion of the compound into the reservoir beyond the reaches of the spray could also have reduced the concentration to a point where it was no longer effective. In the shallow parts where the brilliant sunlight and clarity of the water were evident, NaPCP would dissipate before it could kill the snails. In such places application on a cloudy day or during the late afternoon might be more effective. Estimation by Haskin's method of the concentration of the chemical after application may indicate the reason for some of these failures, but even when this is done samples of water may inadvertently be taken from pockets of high or low concentration and false readings be obtained. It would seem that a number of estimations are therefore desirable.

Poor diffusion of compound was also due to thick vegetation which caused stratification of the chemical in the upper layers of warm water, where the compound was exposed to the ultraviolet rays of the sun with resulting rapid dissipation. Where thick growth of vegetation occurs in static waters, it is recommended that a pump capable of delivering a powerful jet of water be used to cause turbulence of the surface in order to reduce stratification.

In the Union of South Africa, where small rather than large bodies of water are probably responsible for bilharzial transmission, copper sulfate

has been used with varying success. In one extreme only nine treatments were required in four years; elsewhere treatment was necessary every six weeks. In the Transvaal, NaPCP was used in a small spring which flowed from a magnesite deposit. The water was shallow, clear and exceptionally hard (550 p.p.m.  $\text{CaCO}_3$ ). The compound was applied in the headwaters at a concentration of 8 p.p.m. for a period of 48 hours and, although the stream was only 3.5 km in length, snail control was limited to the first 50 metres. This failure was probably due to three factors: (1) the excessive hardness of the water, (2) destruction of the compound by ultraviolet light as it flowed slowly down the shallow stream, and (3) the occurrence of several pools in the course of the stream, which diluted the 8 p.p.m. to such an extent that it was not strong enough to kill snails.

In the Belgian Congo, in order to obtain satisfactory results it has been found necessary to clear vegetation from all streams, irrigation canals and edges of lakes before treating with copper sulfate or sodium pentachlorophenate. The latter has been applied at a final concentration of 10-20 p.p.m. in fast-flowing streams and canals and at a concentration of 50 p.p.m. in the clearer and more alkaline water of Lake Kivu.

Bayer 73 has recently been tried in the Belgian Congo with very promising results. Various concentrations, ranging from 0.5 p.p.m. to 4 p.p.m., were used in several streams. In one experiment, 100% of all snails and snail eggs were killed throughout an irrigation canal for a distance of nearly 7 km with a concentration of only 1 p.p.m. applied for a period of eight hours. The water was fast-flowing and even muddy in places. The efficacy of the compound was not, however, impaired. It would even appear that the turbidity of the water might impede the penetration of ultraviolet rays which, according to laboratory tests, are detrimental to Bayer 73. This compound would, however, appear to deteriorate less rapidly than sodium pentachlorophenate. Removal of aquatic vegetation is not necessary with Bayer 73.

In Tanganyika, NaPCP has been used in irrigation systems on a sugar estate, primarily as a herbicide. Elsewhere, Bayer 73 has been used on an experimental basis with good results in doses as low as 0.2 p.p.m.

In Kenya, attempts have been made to prevent infestation of uninfested irrigation channels with copper sulfate in a dose of 0.125 p.p.m., but snails have become established. Little improvement followed an increase to 0.3 p.p.m., and *Biomphalaria pfeifferi* and *Bulinus tropicus* have been found. Bayer 73 has also been used experimentally in the Nairobi River in a dose of 1 p.p.m.; complete eradication of snails over the area was obtained.

In Mozambique initial experiments with I.C.I. 24223 have been instituted. The compound is very effective in still waters (when dissolved in toluene) in a dose of 0.4 p.p.m. but would seem to be ineffective in running water.

It is evident from the foregoing remarks that copper sulfate and particularly sodium pentachlorophenate are the molluscicides most widely used. The newer experimental molluscicides also seem highly effective in most situations.

It was the opinion of the Conference that effective control measures could and should be instituted at an early date with whichever molluscicide appears to be the best suited to a particular environment, even before certain outstanding problems in bilharziasis epidemiology are solved. Certain suggestions for pre-control consideration are made below, but, bearing these in mind, it is probable that in many areas of Africa south of the Sahara mollusc control is possible at the present time if carried out with enthusiasm.

### **2.3 Problems in the application and evaluation of molluscicides**

It has often been stated that a bilharziasis control programme depends on the effectiveness with which those primarily interested in agriculture and irrigation have been made aware of the public health aspects of the problem. The reverse is also true, since in many instances the failure to obtain co-operation for a control programme is due to lack of understanding on the part of the public health authorities of the agricultural and irrigation problems. As the success of a control programme is likely to be proportional to the amount of common ground that has been found by all persons involved, it is essential that a complete understanding of problems should exist between all interested parties. Since this obviously includes the inhabitants of any area to be treated, an extensive health education programme should be instituted.

#### *2.3.1 Pretreatment requirements*

The Conference considered that the following data are required prior to the implementation of a well-organized molluscicidal programme.

Detailed information should be obtained, with topographical maps of the area showing all water sources and their relationship to human populations.

Quantitative data on intermediate hosts should be gathered, based on standard techniques of snail populations, their eggs and the infection rates in these snails. An assessment of snail populations may be derived from (a) the number and size of each species collected per dip with a net at selected sites, or (b) the number of specimens collected in a given length of time, or (c) the number found adhering to snail traps, e.g., palm or banana leaves or hardboard. The infection rates may be determined by examining snails for the presence of cercariae.

Base-line information is required on the infection rates in the local population, particularly in children under 10 years of age.

The prevalence and incidence of trematode parasites, particularly those found in domestic stock, should be determined by examination of carcasses from abattoirs.

The effect of the proposed molluscicide on the soil, flora and fauna (including fish) in the area to be controlled should be studied.

It is also essential that an accurate estimate should be made of the amount of molluscicide required and this should be included in the total cost of the proposed control programme.

### 2.3.2 *Application of molluscicides*

#### 2.3.2.1 *Choice of compound*

The most suitable molluscicide must be chosen having regard to the funds available and the conditions of waters to be treated, the use of water being made by the indigenous population and local agricultural practices.

#### 2.3.2.2 *Equipment*

The equipment to be used depends largely on the choice of the molluscicide and the nature and accessibility of the water.

For application of molluscicide over a number of hours or more, a drip or bag technique can be used.

For spray application, high-pressure high-volume pumps are desirable if there is access to the water body. The high pressure and volume tend to ensure an even distribution. Where it is not possible to use such a pump, stirrup, knapsack or portable gasoline engine pumps can be utilized. Jet nozzles are usually preferable to soft-spray nozzles.

When using copper sulfate it is essential to use equipment which will not corrode. The plastic Hudson pump with freon cartridge jet should be particularly useful for treating borrow pits, ponds and small bodies of water. On large bodies of water a centrifugal pump can be used.

#### 2.3.2.3 *Dosage*

Particular care and attention should be paid to calculating the dose of molluscicide to be used. Accurate measurement of large bodies of water may be facilitated by the use of maps or aerial photographs. The depth of water should be determined as accurately as possible.

Flow meters or weirs should be used for measuring the velocity for calculating the volume of running water.

The concentration of the molluscicide at a number of points in the water should be ascertained after its application to ensure that uniform distribution of the compound was obtained. Haskin's method for determining the content of pentachlorophenate or the colorimetric method of Strufe for Bayer 73 may be used.

#### 2.3.2.4 *Failures of molluscicidal application*

Failures of molluscicidal application may be due to a number of factors.

Attention must be given to the physical and chemical characteristics of the water and the appropriate molluscicide used. Application of the wrong compound may result in failure.

Insufficient concentration of molluscicide owing to faulty calculations or excessive flooding after application, leading to severe dilution, may result in too low a concentration of compound coming into contact with snails.

Insufficient contact time owing to rapid removal of the chemical by fast-flowing water or rapid breakdown of a compound may lead to failure.

Pocketing of a molluscicide and the occurrence of areas of low concentration of a chemical may enable some snails to survive.

Prolonged storage of a molluscicide prior to use may cause some deterioration, resulting in under-dosage of the waters.

Extensive control programmes when efficiently executed ensure much better molluscicidal success than programmes in small areas.

Thorough mollusciciding of headwaters of streams, seepage areas, "vleis", etc., must be ensured. Although not important sites of infection, such places may be the source from which areas previously made free of snails through the use of molluscicides can be repopulated.

Every endeavour should be made to commence mollusciciding as high up a river or irrigation system as possible.

Evidence suggests that a certain proportion, although low, of the snails of some species may aestivate during the dry season. This possibility should be borne in mind in mollusciciding programmes and the treatment of the waters made accordingly.

#### 2.3.3 *Post-treatment observations*

Following the application of a molluscicide, observation of the waters should be made at regular intervals with the object of determining the presence of snails. The techniques used should be the same as those employed prior to treatment, in order that an accurate assessment of the effect of the molluscicide can be obtained. Further assessment may be made by placing in the waters immediately prior to mollusciciding plastic containers (of coarse mesh) in which snails, their eggs and a little vegetation are placed. The mortality or morbidity that occurs following mollusciciding can then be readily assessed. A comparable control sample of snails and eggs should be placed in similar containers in untreated water.

Regular checks on the incidence, based on cases of bilharziasis in children under the age of 10, should be continued, using the same methods as were used in the pretreatment survey. A significant decrease in the

prevalence of infection will reflect the success of the control measures adopted.

Examination of carcasses at abattoirs, comparable with those carried out before treatment, should be made in order to show the incidence of animal distomatosis. In this way the measure of success of the mollusciciding programme may be assessed with less delay.

#### 2.3.4 *Indications for retreatment with molluscicide*

Retreatment should be undertaken with as wide a margin of safety as possible. When eradication of snails is intended, this involves fresh molluscicidal action as soon as any young snails appear and before they are old enough to lay eggs. When control of transmission only is intended it may be sufficient if treatment is carried out before any of them are old enough to shed cercariae.

### 2.4 Further recommendations

#### 1. *Manual of the principles of mollusciciding*

It was suggested that certain countries hesitated to initiate molluscicidal programmes because of a lack of knowledge and lack of guidance in employing various criteria which would lead to successful control.

A request was made that WHO prepare a manual dealing with the principles and the various phases of mollusciciding.

#### 2. *Place of herbicides in snail control*

Waterways which are choked with aquatic vegetation often afford very suitable habitats for snails. Since removal of such vegetation by chemical means would facilitate molluscicidal control, a recommendation to investigate the use of herbicides in bilharziasis control was made.

## 3. WATER MANAGEMENT, LAND USE AND AGRICULTURAL PRACTICES IN RELATION TO THE TRANSMISSION AND SPREAD OF BILHARZIASIS

### 3.1 Review of existing regulations in African territories on diseases and vector control as related to the development of water resources

#### 3.1.1 *The present position*

The Conference noted the almost complete lack of regulations concerning the control of water in rural areas of Africa south of the Sahara, except where interests other than public health, such as water conservation,

agriculture and fisheries, are concerned. In some urban areas local government ordinances are available but are not always effectively enforced. In the Belgian Congo, a specific public health ordinance has been promulgated and in Southern Rhodesia an advisory committee has been formed to consider all aspects, including health.

It was also noted by the Conference that in many districts regulations may be unenforceable, particularly if they are made without due regard to local problems, such as the cultivation of marginal-yield smallholdings, local superstition and administrative difficulties, or where they interfere with essential industries such as production of fish, rice, etc.

The Conference considered that the snail breeding sites may be conveniently divided into natural and artificial collections of water. The principal need for regulations is with the latter variety, which are steadily increasing in number. These regulations should be framed to embrace as many public health problems as possible. However, it was considered that prior to the introduction of specific legislation, attempts should be made to achieve the control or amelioration of the diseases by advice and public health education, not only for the people at risk but also, as is often necessary, for administrators and technical officers of other departments.

### 3.1.2 *Existing and suggested regulations*

Some of the countries in the African Region have already made a beginning towards establishing legislation on the control of vector-borne diseases. In 1959, the Belgian Congo passed Ordinance No. 74/569, establishing certain rules for the protection of public health, to be observed in the working of irrigated land. The following quotations from this Ordinance indicate the approach made.

“ ...

Considering that irrigated land may provide favourable breeding places for several vectors of endemic diseases and that it is essential to limit as far as possible the danger which this may constitute for public health, [the following regulations will be enforced].

#### *Article 1*

No irrigation network (except those consisting of closed conduits) or land irrigation systems (except by spraying or subterranean infiltration) shall be installed or operated except in accordance with the provisions of the present Ordinance.

#### *Article 3*

All irrigation networks shall be equipped with a hydro-technical device permitting at any time the rapid evacuation of excess water and the sudden fluctuation of the water level.

#### *Article 4*

... any person cultivating land shall, at his own expense, apply all measures deemed desirable by the local health authorities for the prevention of proliferation of vectors

of endemic and other diseases which may result from the existence of his irrigation network. The prophylactic measures shall be applicable over the whole of the irrigation network.

*Article 5*

...  
On the advice of the health authorities, all illegal or unhealthy installations which have not been demolished or converted within the time-limit set by the health authorities may be automatically demolished or converted at the offender's expense."

The above is an example of the way in which legislation directed towards control of the intermediate host might be accomplished. In each country it would be necessary to take local conditions into consideration, and in each case it is important to adapt measures to the local needs and to keep regulations within practical limits. It is essential that public health authorities stress the importance of such measures, but at the same time they must consider the non-medical aspects of the problem.

It is also of critical importance that the need for the proposed regulations be supported by scientifically established facts.

### **3.2 Inter-agency co-operation in development of water resources in connexion with disease and vector control**

As there must be the fullest co-operation between all agencies involved in the development of water resources, it would be advisable to set up co-ordination committees within the framework of national organizations in order to review such development schemes. Public health agencies, however, are often unwelcome in such councils as their attitude is frequently considered to be negative and restrictive by bodies concerned in the development of natural resources. The public health agencies must realize the prime importance to the people of irrigation and other developments and must be prepared to offer concrete and positive advice as to how disease control measures can be integrated into the project.

It is obvious that no single existing governmental department has been able to handle the complicated problem of bilharziasis control. It is essential, therefore, that each government establish a national water resources commission for the purpose of co-ordinating and integrating the various interests—such as irrigation, agriculture and public health—in the over-all planning for the development and utilization of water and related land resources. Because of the broad aspects of this problem it also will be necessary to enlist the co-operation of such international agencies as FAO, WHO, ICA, etc.

It is believed that the philosophy behind resource development, particularly in irrigation schemes, needs reassessment in the African Region. The planning of many of these projects is based on the expectation that

the annual income will be as much as or more than the initial capital investment. Under such circumstances it should be possible to construct systems that would be less likely to serve as breeding sites of disease vectors and more amenable to other methods of control. In many parts of the world the investment in such projects is amortized over a period of 10-50 years. In some countries it has been possible to make a levy on the total income derived from the over-all scheme to provide for public protection.

### **3.3 Use of engineering methods in programmes of development of resources in connexion with the control of diseases and vector control**

#### *3.3.1 Introduction*

The economic development of many countries in Africa depends on the full utilization of their water resources. The construction of dams to impound water for human and domestic animal consumption, for irrigation systems and for power production increases the number of breeding places for a variety of invertebrates that transmit diseases to man. Several of these diseases are being brought under control but the prevalence and intensity of bilharziasis infections continue to increase. At present, the most effective method for controlling bilharziasis is to eliminate the snail intermediate hosts. As data on the habits and environmental requirements of the snails have become available, it has been found that certain changes in the habitats make them unsuited for the maintenance of snail colonies. For the most part, such changes require corresponding changes in the planning and construction of the facilities for water conservation and its use. It will not be possible to eliminate all of the colonies in this way but those that remain can be controlled with molluscicides.

An investigation has been made on the prevalence of bilharziasis and its relationships to irrigation engineering, freshwater ecology, agricultural methods, hydro-electric schemes, and the development of communities in affected areas. The broad aspects of the problem made it necessary to consider the national economy and the co-ordination of the activities of the various agencies involved in such projects. It was hoped that these studies would result in defining certain engineering principles that would be useful in controlling disease, and that these would be practical enough for consideration in the planning and implementation of water resource development.

Water management problems should be considered from the point of view of natural water bodies with either too little or an excess of water, or of man-made water bodies designed to conserve water. As it is often excess water which contributes to health problems, it is necessary to consider drainage, ponding, filling or other methods of control. Of the man-made

water bodies, the irrigation systems are of particular importance. Many precautionary measures are possible which inhibit development of vector populations and in the majority of cases these measures are consistent with sound irrigation practices.

### 3.3.2 *Irrigation and agricultural methods*

In many endemic areas greater progress has been made with regard to the engineering aspects of irrigation than in the utilization of the water. The former requires little or no initiative on the part of the water users and is in the hands of specialists. Primitive agricultural practices and poor irrigation methods at the water-user level are the primary weaknesses of such systems and are also a major contributing factor in the spread of bilharziasis. There is evidence from some areas that a combination of water management and improved agricultural methods can be used to increase production and to reduce the transmission of bilharziasis. The dual benefits that may be derived from such an approach indicate that these methods should be tried in other areas.

In the early phases of a pilot control project in the Philippines it was found that the nature of the terrain and the extent of the snail habitats precluded the effective use of molluscicides. The use of a combination of improved agricultural methods, drainage and the control of irrigation water has given promising results. In the areas under control over the past two to four years, the snail population reduction has averaged 95%. In many areas snails have been eliminated and the remaining pockets are amenable to control by molluscicides. At the same time, land that had not been productive is now very valuable and contributing to the local and national economy. In other areas, where rice had been grown by primitive methods and snails were numerous, water management and improved agricultural methods have eliminated or markedly reduced the snail population. In some cases the crop production has trebled. A complete evaluation of these methods as a disease control measure is not yet available but preliminary surveys show that there has been a significant reduction in the bilharziasis prevalence among schoolchildren in the experimental area, while this has not been true in the control area.

The Miwani Sugar Estates, Kenya, consist of 2500 acres (1000 hectares) of sugar cane under irrigation and future plans call for an extension to 4000 acres (1600 hectares). The water is pumped from the Ainomotua River. *S. mansoni* and *S. haematobium* are endemic in the surrounding area. There has been little or no snail breeding in the Estates' irrigation system, the irrigation and agricultural methods used apparently having countered the usual extension of bilharziasis into irrigation systems. The well-planned and well-designed distribution and drainage system was constructed from the beginning on land that had been properly graded.

Water is conserved by being delivered to the field laterals by pipe, and metal siphons are used to convey it to the field furrows. The soil is tested for moisture content and water is not allowed to flow in the laterals until it is needed in the fields of that block. This results in a definite rotation cycle with as much as 15 days between relatively short irrigation periods. Modern heavy equipment is used for constructing and maintaining the system because it has been found cheaper than manual labour in the long run. Herbicides are used to control vegetation in the canals and drains for the same reason. Yields of 120-140 tons per acre are produced and in spite of the rather large capital expenditure this operation apparently has been a sound investment. Measures of this sort are possible where control is centralized and are economically feasible if the crops have a high commercial value. It would be difficult to justify and impossible to carry them out in areas where small, hand-cultivated holdings are primarily devoted to subsistence farming.

The cultivation of rice is often associated with a high prevalence of bilharziasis. However, in some areas in Ghana this is not the case. There are at least two important basic differences between this country and many other rice-growing countries: (a) the soil is of a type that is not easily tilled by hand; and (b) population pressures have not reached the point where the land and labour are divided among as many individuals as possible. Both of these facts encourage the use of mechanical cultivation, sowing and harvesting. The agricultural methods that have been devised at the Kpong Experimental Farm further reduce the chances of bilharziasis transmission. These include: (a) drilling the seed into dry soil; (b) irrigating only long enough to obtain germination; (c) turning water off for about four weeks; (d) irrigating again until the rice blooms; and (e) allowing the fields to dry out for harvesting. This irrigation-agricultural regimen appears to upset the snail and parasite cycles.

Reports on the effectiveness of the lining of canals and the use of efficient regulator structures as snail and bilharziasis control measures have been varied. For this reason and because of high capital costs, engineers will not use lining unless it is warranted on other grounds. The fact that snails are eliminated in some areas and not in others indicates that the way the canals and regulator structures have been built and used is important. In Puerto Rico and in Israel it has been shown that snail breeding does not usually take place where water velocities are 30 cm or more per second. It has been shown in endemic areas that some species of snail can survive for as long as several months in habitats that are allowed to dry. The fact that these survivors soon repopulate the habitat has tended to discourage the use of this method of control. Fortunately, the infected snails die first under such conditions; it requires at least a month for a significant return of the snail population, and then it requires about four weeks more for a newly infected snail to produce cercariae.

These facts indicate that the snail and parasite cycles might be kept continually "off balance" by adopting certain water-use regimens and adapting agricultural methods to them.

There are some additional factors that are involved in the engineering and disease control aspects of the development of irrigation. Canal systems that have been built with low gradients tend to fill with silt and become choked with vegetation. The intermediate hosts find excellent habitats in such canals and maintenance costs are high. For example, in the Gezira (Sudan) with about one million acres (or a little over 4000 km<sup>2</sup>) under irrigation, the annual cost of vegetation removal is S£ 50 000 and of silt removal S£ 250 000; the initial cost of sulfation for snail control was S£ 238 339 and the annual cost is S£ 65 000. The control of one of these nuisances may result in the control or marked reduction of the others. The possible annual saving of amounts of this magnitude may warrant consideration of an increased capital investment in the planning of such schemes.

Snail control by the use of water management will be easier in irrigation systems with lined canals and efficient regulator structures than in those with earth banks. For this reason it would be useful to make a study of existing canal systems of the former type in African countries in order to determine what factors contribute to snail control and what improvements could be made. The engineering and agricultural features to be studied should include: types of practical canal lining and regulating structures; measuring weirs; water velocities; the use of conduits and siphons; the possible use of water rotation regimens to control snail and parasite cycles; and an attempt to correlate the modified rotation patterns with agricultural methods.

The next step would be to apply, adapt and experiment in other areas with the methods suggested by the above study. Under certain conditions these could be carried out in established schemes, such as those mentioned above, in innumerable schemes with earth canals, or in schemes in the planning and development stage. Because of the nature of the problem, it would be necessary for the agencies involved in this phase to supply experts in agriculture, engineering and medical zoology. Assistance from specialists in epidemiology and statistics also would be essential. A project of this type should be continued for at least five years before an evaluation is made of its effectiveness and practicality.

### 3.3.3 *Stream and watershed control, combined with land reclamation*

In many areas bilharziasis is associated with marshy, slow-moving streams. In such areas, the conditions that have created the snail habitats prevent the full utilization of a great deal of fertile land. Ecological and malacological studies have shown that the snail infestation pattern tends

to follow that of watersheds. It is often true, however, that not all of the apparently suitable watersheds or habitats within these topographical units are infested. The fact that drainage, stream channelling and land reclamation in some areas have reduced or eliminated snail populations indicates that these methods are worthy of trial in others. To do this, it will be necessary to survey areas selected for such trials and determine which methods will be most effective and economically justifiable under local conditions.

Certain aspects of the bilharziasis control problem in Leyte, Philippines, have been mentioned in the previous section. As a part of the engineering approach to control in this type of area, it has been demonstrated that drainage and stream channelling will reduce or eliminate snail colonies. As a result of these measures it has been possible to raise corn, rice and other crops on formerly useless land. The measures have reduced the snail-infested area to one-tenth of its former extent.

In 1950, the Latanière River in the vicinity of Port Louis, Mauritius, was canalized and drains were installed. This was done as a mosquito and malaria control measure. Before this work was done it had been shown that the stream served as a habitat for the local vector of *S. haematobium*. In 1952, a survey in the nearby school showed that 63% of the children had bilharziasis. In 1959, snails were present in parts of the stream above the canalized portion but were not found where the mosquito breeding sites had been eliminated. Seven years after the previous survey in the schoolchildren, it was found that only 25% were infected.

Before measures of this sort could be put into practice elsewhere it would be necessary to make a complete survey of selected watersheds. The survey area should have a series of marshes and other snail habitats, prevalence of bilharziasis in the human population should be high, and the area should have potentialities for agricultural development. The survey should include studies on the distribution of the snails, the prevalence of infection in snails and man, and the engineering measures that would be required to eliminate or markedly reduce transmission. It should be pointed out that unjustified interference in some ecological situations may create conditions which favour the introduction and breeding of the snail intermediate hosts. The report on the engineering measures would include estimates on their cost and the value of the reclaimed land.

#### 3.3.4 *Control in ponds and reservoirs*

The development of arid and semi-arid areas depends on water conservation and storage. In other areas, fish ponds are considered essential as a source of protein for the human population. The resulting bodies of water may vary in size from small farm ponds for watering stock to that of reservoirs used as water supplies or for power production for metropolitan

areas or both. All tend to increase the number of snail habitats and tempt the people to use them for recreation or domestic purposes. If there is pollution and human contact with them, the stage is set for an increase in bilharziasis transmission. These bodies of water are essential and it is not intended to advise against their development. It is important, however, to convince administrators that such developments must be made less dangerous as disease transmission sites.

The clearing and deepening of reservoir sites before filling, the fluctuation of water levels, and vegetation clearance have been used successfully by the Tennessee Valley Authority in the USA for mosquito control. Enough ecological and malacological data are available to indicate that these methods might be adapted in some areas to control snail populations and the trematode infections that they transmit. For this type of control a survey should be made of a watershed that has one or more infested ponds and where the water loss due to water level manipulations could be replaced without seriously restricting the water supply for man, animals and agricultural activities. If the experiments showed promise the engineers might be induced also to clear and improve the reservoir basin. Many of the older ponds with flat contours already have lost a considerable amount of their storage capacity. The experiment could become a part of a pilot control project. It could not be undertaken, however, unless full co-operation was enlisted from the various agencies now involved in the construction and maintenance of the dams. An assessment of the value of such measures would require three to five years. While large dams and reservoirs for multipurpose use (hydro-electric works, irrigation, water transportation, etc.) are relatively few as compared with dams and ponds for agricultural use, the above-described measures may be even more applicable to the former than to the latter and therefore should receive careful consideration, preferably in advance of development of these large projects.

The restriction of human and domestic animal access to ponds has been a factor in controlling trematode infections in the Union of South Africa and the United States of America. This has been achieved by fencing the ponds and installing suitable water take-offs for human and domestic animal use. This method is being used in the Savannah Project area now being developed in Ghana.

In the past various ponds and reservoirs in Southern Rhodesia have been involved in bilharziasis transmission. Until recently the use of shores of artificial lakes for recreation has been unrestricted. When the Kyle Dam was built the Irrigation Department bought a strip of land 300-feet (90-m) wide above the high water mark of the reservoir. As a result it has control of the use of the lake. Allocation and maintenance recreation sites and sites of intensive population contact will be controlled with due consideration of health aspects, and the controlling authority has been advised to allocate these sites only in those sections of the shore line where snails are

least likely to occur. It is too early to tell whether this method of control will be effective but such an approach is encouraging.

### 3.3.5 *Rain-water as an alternative water source*

In many parts of Africa ground-water is not available or is not potable. This forces the people to use all sorts of surface water. These sources tend to be heavily polluted and many serve as habitats for snail intermediate hosts and as infection sites for many diseases. These sites cannot be eliminated until another source of domestic water is available. In certain areas the use of rain-water storage as this source should be investigated. If rainfall is adequate and suitable storage facilities can be constructed, the infection sites could be eliminated. In many relatively arid parts of the world, rain-water is the chief source of potable domestic water. In Ghana and Togo, it has been observed that rain-water was not being sufficiently utilized. A preliminary analysis of rainfall data and some estimates of the water collection potential of suitable roofs in villages indicated that with adequate storage facilities rain-water could be used to replace the polluted surface water. For example, it was calculated that the roof area of a health centre in Togo could collect eight times the amount of the annual water ration that was hauled by truck from a nearby reservoir. This estimate allowed for a 60% loss of the annual rainfall.

An investigation of the possible use of rain-water as a domestic water source should include the following steps: (a) make a survey of available rainfall data; (b) estimate the cost of the necessary storage facilities; and (c) select areas where the method could be used. It is believed that several of the West African countries offer areas where the use of rain-water as a domestic water source is feasible. It is estimated that the first two steps would require about six months, if the local meteorological data are adequate. If the survey indicated that rain-water storage was a practical measure, one or more areas should be selected for the determination of the most practical methods and the collection of data as a demonstration of their value.

### 3.3.6 *Prevention of contact, pollution and contamination*

Methods for preventing human contact with polluted water which may contain cercariae would include the building of bridges and culverts over streams and canals. In their construction care should be taken not to create breeding places adjacent to them. Borrow pits that may be associated with bridge and road building should be filled or drained.

The installation of safe washing places of a design acceptable to the people would eliminate one type of exposure to bilharziasis. The use of funds for this purpose would be justified only in places which are potential transmission sites.

The construction of safe wading and splashing pools in key locations would also tend to reduce the exposure among children. An effective educational programme concerning the dangers of natural waters would increase the value of this measure.

### Annex

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