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EPIDEMIOLOGY AND CONTROL OF SCHISTOSOMIASIS

Report of a WHO Expert Committee

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**WHO EXPERT COMMITTEE
ON EPIDEMIOLOGY AND CONTROL OF SCHISTOSOMIASIS**

Geneva, 12-17 December 1966

Members:

- Professor L. Brumpt, Chair of Tropical Diseases, Faculty of Medicine, University of Paris, France
- Dr M. Farooq, Former Senior Adviser, Bilharziasis Control Pilot Project and Training Centre, Alexandria, UAR
- Dr R. E. Kuntz, Chairman, Department of Parasitology, Southwest Foundation for Research and Education, Southwest Research Center, San Antonio, Texas, USA
- Professor Adetokunbo O. Lucas, Head, Department of Preventive and Social Medicine, University of Ibadan, Nigeria
- Dr D. B. McMullen, Scientific Adviser, Walter Reed Army Institute of Research, Washington, D.C., USA (*Rapporteur*)
- Dr F. Rizk Hassan, Under-Secretary of State, Ministry of Public Health, Cairo, UAR (*Vice-Chairman*)
- Mr G. Webbe, Scientific Staff, Farbenfabriken Bayer AG, Wuppertal-Elberfeld, Federal Republic of Germany
- Professor T. H. Weller, Chairman, Department of Tropical Public Health, School of Public Health, Harvard University, Boston, Mass., USA (*Chairman*)
- Dr W. H. Wright, Former Chief, Laboratory of Parasitic Diseases, National Institutes of Health, Bethesda, Md., USA

Representative of the Food and Agriculture Organization of the United Nations:

- Dr J. O. Deom, Chief, Section of Veterinary Research and Education, Animal Health Branch, Animal Production and Health Division, FAO, Rome, Italy

Secretariat:

- Dr N. Ansari, Chief, Parasitic Diseases, WHO, Geneva (*Secretary*)
- Dr W. R. Jobin, Research Sanitary Engineer, Tropical Disease Section, Communicable Disease Center, US Public Health Service, San Juan, Puerto Rico (*Consultant*)
- Dr E. A. Malek, Associate Professor, Department of Tropical Medicine and Public Health, School of Medicine, Tulane University, New Orleans, La., USA (*Consultant*)
- Professor G. S. Nelson, Department of Helminthology, London School of Hygiene and Tropical Medicine, London, England (*Consultant*)
- Dr L. J. Olivier, Adviser on Parasitic Diseases, WHO Regional Office for the Americas, Washington, D.C., USA
- Dr B. A. Southgate, Senior Parasitologist, Division of Insect-Borne Diseases, Medical Research Laboratory, Nairobi, Kenya (*Consultant*)

EPIDEMIOLOGY AND CONTROL OF SCHISTOSOMIASIS

Report of a WHO Expert Committee

A WHO Expert Committee on Schistosomiasis met in Geneva from 12 to 17 December 1966. Professor T. H. Weller was elected Chairman, Dr F. Rizk Vice-Chairman, and Dr D. B. McMullen Rapporteur. Dr P. Dorolle, Deputy Director-General, opened the meeting on behalf of the Director-General.

INTRODUCTION

In the two years that have elapsed since the meeting of the previous committee, much progress has been made in the knowledge of schistosomiasis, as the outcome of intensive research carried out over the past decade. New techniques have been developed for conducting epidemiological surveys indispensable to determining the importance of the disease in endemic areas and to investigating the many factors that contribute to its transmission. A number of control methods have been tested in the field and have proved successful, and continuing evaluation of chemotherapeutic agents and dosages is establishing their advantages and limitations in combating schistosomiasis. While laboratory and operational research continues on control methods, better knowledge is being gained of the pathogenesis and pathology of schistosome infections through parasitological, immunological, clinical, radiological, and post-mortem studies.

As is the case with other parasitic diseases, it has become evident that while research on schistosomiasis has received a tremendous impetus from fast-progressing technology, application in the field—i.e., control of the disease—is proceeding at practically the same pace as before. Knowledge is accumulating but there is no opportunity for it to be tested sufficiently. In order to improve present control techniques, they must be put to field use, their results evaluated under different epidemiological conditions, and their defects recognized. This creates a need for standardized techniques and procedures, so that valid conclusions can be drawn from the various data received.

The gap is widening between research workers and those who are actually faced with the task of fighting schistosomiasis, and it appears that WHO may be of particular assistance by publishing reports on tech-

niques that have been proved effective, as was the case with the monograph *Snail Control in the Prevention of Bilharziasis*.¹

This report briefly summarizes present knowledge of a number of subjects related to the epidemiology and control of schistosomiasis, and draws attention to recent work deserving of special mention. In addition, recommendations concerning research and the future course of control programmes are made.

1. PARASITOLOGY

Since the meeting in 1964 of a WHO Expert Committee on Bilharziasis² there have been a number of outstanding developments in knowledge of the schistosomes and of relationships between the parasites and their hosts.

1.1 Morphology and physiology

1.1.1 *Miracidia*

The miracidium has been found to have a well-developed "scanning" ability and this may compensate in part for the adverse effects of various factors which tend to jeopardize continuation of the cycle. Recent studies have shown that free-swimming miracidia are stimulated by and attracted to various compounds, and that they make both purposive and non-purposive movements in response to certain chemical stimuli.

Further study of methods of detecting and estimating the numbers of miracidia in natural habitats is desirable.

Penetration probably is achieved by a combination of muscular effort and lytic substances, but the precise mechanism involved is unknown. Recent work has indicated that only a small proportion of miracidia that enter even a susceptible molluscan host actually develop into mature mother sporocysts. Successful establishment of infection is thwarted if the parasite migrates into resistant compact tissues of the snail or is confronted with miracidial-immobilizing substances.

Research with *Schistosoma mansoni* has demonstrated the extensive migration of daughter sporocysts through snail host tissues. Descriptions have been given of the histological and pathological changes accompanying the development of *S. mansoni* in *Biomphalaria glabrata*.

Infection reduces the egg-laying ability of the snail. High mortality among infected molluscs coincides with heavy emergence of cercariae and with the appearance of a severe generalized proliferative tissue reac-

¹ *World Health Organization: Monograph Series*, No. 50 (1965).

² *Wld Hlth Org. techn. Rep. Ser.*, 1965, 299.

tion, caused by cercariae trapped and dying in the loose vascular tissues of the host.

1.1.2 *Cercariae*

Continued studies of the cercarial stage have resulted in additional basic information. Experimental work in East Africa and Puerto Rico has indicated that for infection to occur, there is an optimum speed of flow of the water to which a host is exposed. Other investigations have shown that there are marked seasonal differences in the production of cercariae by snails and that these differences are more pronounced with *S. mansoni* than with *S. mattheei*. Transmission is dependent upon a number of biological factors in the habitat but it now seems that seasonal variations in transmission, at least in South Africa, may be more marked than was previously supposed.

Accurate techniques for demonstrating cercariae in their aquatic habitat are important in epidemiological studies. Continued efforts in Puerto Rico have provided and evaluated new methods for the detection of *S. mansoni* cercariae. As a result of extended studies it has been suggested that for detection of free-swimming cercariae, a combination of the paper filtration technique and the exposure of rodents to suspected waters may be the method of choice at this time.

1.1.3 *Schistosomula*

Studies of schistosomula have continued, with emphasis on their biology in the early phase of migration within the definitive host. Upon removal from the host, schistosomula can survive for limited periods in special maintenance media composed mainly of saline and serum; they are, however, unable to survive in water and can no longer produce pericercarial envelopes when placed in antiserum.

There is some evidence that in experimental animals some of the migrating schistosomes pass from the lungs through the diaphragm to the portal vein.

1.2 Taxonomy of the schistosomes

Proper classification of schistosomes at the species level continues to be a perplexing problem to investigators concerned with the epidemiological and zoonotic aspects of schistosomiasis.

It has been known for several years that geographical strains of *Schistosoma japonicum* differ markedly in their infectivity to both their intermediate and definitive hosts, the extreme example being the Taiwan strain which is zoophilic and non-infective to man. With *S. mansoni* such a marked divergence has not been recorded, but comparison of strains from Africa and Puerto Rico has shown that they differ in morphology,

in infectivity to the intermediate snail host, and in infectivity and pathogenicity in animals. Morphological differences in the eggs and variation in infectivity to the snail hosts have been well documented for geographical strains of *S. haematobium*, but there are as yet no data on differences in the behaviour of the worm in the definitive host. Hybrids may occur between *S. haematobium* and related species such as *S. mattheei*.

This whole subject requires much further study; it is particularly important to determine if variations in the biological characteristics of schistosomes account for differences in their pathogenicity and epidemiological characteristics as observed in different areas.

1.3 Snail/parasite relationship

A new strain of *Oncomelania formosana*, *O. f. chiui* (syn. *Tricula chiui*), from a new focus in northern Taiwan, has been experimentally infected with four of the strains of *S. japonicum* that infect humans, and a strain of *O. formosana* from the Ilan area in Taiwan has been similarly infected with two such strains of this parasite. These findings are of epidemiological interest because of population movements to the island from areas where human schistosomiasis is endemic.

1.4 Animal hosts of schistosomes

The significance of lower animals in the transmission of *S. japonicum* is well established and is of concern in areas where control schemes are in operation. Only very few animals have been found naturally infected with *S. haematobium*; they include rodents, the domestic pig, monkeys, and the chimpanzee. In all cases, however, these have been isolated discoveries and there is no evidence that the animals are true maintenance hosts of the parasite. With *S. mansoni*, much higher infection rates have been recorded in animals, especially rodents and baboons, but usually only in areas where the infection is endemic in man. There is, as yet, no evidence to suggest that *S. mansoni* can be maintained in an animal community, and the extent to which animals enhance transmission to man is not known. In most regions *S. mansoni* is maintained by inter-human transmission. It is recommended that further studies be carried out to assess the significance of animal reservoirs in the more remote rural areas.

Many other species of schistosomes occur in wild and domestic animals. Some, like *S. mattheei*, are of significance because they often infect man. Others, like *Orientobilharzia harinasutai* and *S. margrebowiei*, cause confusion because their eggs closely resemble those of *S. mansoni* and *S. japonicum*, respectively; still others, like *S. spindale*, are important because they cause cercarial dermatitis.

Of perhaps more significance may be recent laboratory studies on *S. mattheei* and *S. bovis*, which suggest that these animal schistosomes can markedly modify the severity of challenge infections with *S. mansoni* and *S. haematobium*; however, the possible significance of natural heterologous immunity has not yet been investigated in man.

2. EPIDEMIOLOGY

2.1 Geographical distribution

Since the meeting of the WHO Expert Committee on Bilharziasis in 1964, more evidence has been accumulating regarding the occurrence of *S. japonicum*, and schistosomes resembling it, in eastern Thailand and western Laos in the Mekong valley. This area should be kept under constant review. Both *Oncomelania* and *S. japonicum* occur in the upper reaches of the Mekong River in mainland China, and it is likely that regional developments along the Mekong have provided suitable habitats for *Oncomelania* and will make possible the transmission of *S. japonicum* in the area. However, two aspects should be noted: (1) limited surveys conducted in Laos and Cambodia during 1960-62, and several others conducted in Thailand, did not reveal the presence of *Oncomelania* snails; and (2) several species and strains of *Oncomelania* from various countries in the Orient did not show any susceptibility for the schistosome from Thailand and Laos, which has tentatively been identified as *S. japonicum*. The above facts throw some doubt on the identity of this schistosome, and the Committee urges that more work be done on the identity of the species occurring in man, as well as those of animals, in South-east Asia.

In Japan there has been a reduction in schistosomiasis caused by *S. japonicum*, mainly as a result of chemical control, habitat modification, and changes in types of agriculture and industrialization in the relatively small foci in the country. In mainland China the campaign against schistosomiasis is an integral part of the national programme for agricultural development, and it is said that there has been a marked reduction in the prevalence of the disease as a result of combined attack on both the parasite and the snail intermediate hosts.

As to the situation of the schistosomiasis focus in India, the possible relationship of the several species of schistosomes of animals in that area to the species described in the Ratnagiri District of Maharashtra State requires further study. It has been reported that *Ferrissia tenuis* is the snail intermediate host of *S. haematobium* in that focus. The Committee recommends that the susceptibility of the ancyloid snail species occurring in Africa to members of the *S. haematobium* complex should be investigated.

It has been reported to the Committee that a recent survey has indicated that *S. haematobium* is now extinct in Algarve, Portugal.

Extension of the distribution of *S. mansoni* has been reported from several areas. In Brazil there has been a spread of the disease into the southern states and in the State of Maranhão, and there is further evidence of an increase in the endemicity of *S. mansoni* following agricultural development using certain forms of irrigation. A similar situation exists in Africa, where there is evidence of the occurrence of new foci of *S. mansoni* and *S. haematobium* in areas where there are many small systems for the improvement of water supply, mainly for the livestock industry. Even in areas where large irrigation systems exist, and where the special skills necessary for the control of schistosomiasis are available, there is evidence that the disease is on the increase.

The possibility of increased intensity of transmission of both *S. haematobium* and *S. mansoni* as a result of the spread of perennial irrigation in Egypt following the construction of the High Dam must be considered. On the other hand, mention should be made of the successful pilot control of both *S. haematobium* and *S. mansoni* in the Egypt-49 project,¹ where transmission of schistosomiasis has been interrupted in the area under control.

In Israel the *S. mansoni* focus in the Yarkon River area has completely disappeared.

The application of control measures has resulted in a reduction of the prevalence of the disease in both Puerto Rico and Venezuela.

In the past schistosomiasis has been commonly referred to as a rural disease. The Committee notes, however, that transmission can occur even in urban areas if favourable conditions exist.

2.2 Dynamics of transmission

The third report of the WHO Expert Committee on Bilharziasis² considered at some length the main factors involved in the transmission of schistosomiasis and the advantages to be gained from mathematical analysis of these factors, and "noted the efforts that have been made to obtain quantitative estimates for the factors in the transmission of *S. haematobium* and *S. mansoni*". The Committee then strongly recommended "the establishment of research teams for the purpose of obtaining the data that are necessary for testing the model against these two species".

In the interim, further information on the use of mathematical analysis has appeared, and additional equations for transmission variables have been developed. The Committee recognizes the importance of

¹ Bilharziasis Control Pilot Project and Training Centre, sponsored by the Government of the United Arab Republic and jointly assisted by UNICEF and WHO.

² *Wld Hlth Org. techn. Rep. Ser.*, 1965, 299.

these advances and is confident that such methods will assume increasing value as the variables are defined. In the meantime, the Committee cautions against delay in the application of control procedures on the grounds of incomplete knowledge of epidemiology. Moreover, at this time reliance should not be placed on mathematical analysis *per se* in the formulation of control projects. From a practical standpoint, all available information on an area of proposed operations should be carefully reviewed in planning control programmes.

The Committee has taken note of new information that has altered previous concepts of the epidemiology of schistosomiasis. Such information is discussed elsewhere in this report, but two areas deserve special emphasis here: the survival of adult worms and the "scanning" ability of miracidia.

2.2.1 *The survival of adult worms*

It is commonly stated that schistosomes live for many years. This statement is based on the finding of viable eggs in the excreta of patients who have resided outside an endemic area for prolonged periods. For example, worms have been shown to survive for 20 or 30 years in individuals who have moved from endemic areas. Actually, it is possible that the schistosomes that infect man may have a short average life span. In the Egypt-49 project area, it has been observed that, in the absence of re-infection and treatment, a high proportion of children cease to pass eggs within 3 years. In children under 5 years of age this occurs at the rate of 48% per year in the case of *S. haematobium* and at the rate of 58% per year in the case of *S. mansoni*. In older children it takes place more slowly. It has been estimated that the death rate of female *S. japonicum* is about 25% per year.

If the cessation of egg excretion reflects the death of worms, the mean length of life of female schistosomes may be as short as 2 years and is probably not greater than 5 years. Such estimates, if substantiated, could have considerable epidemiological significance. It should be remembered, however, that they are based on data from children and the life span of worms in adults may be different. Moreover, conclusions concerning average life span must be applied to epidemiological situations with caution, since the extremes of life span may also be very important.

2.2.2 *The "scanning" ability of miracidia*

Only in recent years has the ability of the newly hatched miracidium to traverse its water environment in search of a snail been investigated. Studies in the laboratory have revealed that the miracidium has the ability to make extensive lateral and vertical movement. More recent work indicates that, up to a point, the chance of a snail's being infected

is increased by water flow, even when few miracidia are present. If these laboratory observations could be substantiated by evidence from the field, it would mean that a very small snail population might maintain transmission.

3. HEALTH AND ECONOMIC IMPORTANCE

A consideration of the public health importance of an infection takes into account its frequency; the common range of its ill-effects and their relative severity and frequency; its distribution amongst various age, sex, occupational, and other groups of the population; its social and economic effects; and its contribution to morbidity and premature mortality.

3.1 Measurement of economic importance

To assist in the allocation of limited resources for health programmes, assessment of the economic importance of schistosomiasis is essential. The Committee has reviewed the very limited information on the economic consequences of this disease in various parts of the world. Present methods of collecting such information are not completely satisfactory and studies designed to improve them are desirable.

3.2 Measurement of public health importance

The application of new techniques to community surveys designed to assess the health significance of schistosomiasis has provided important information, particularly on the status of *S. haematobium* in parts of Africa.

The introduction of techniques for the counting of egg output (see section 5.1.1) has been of great value. Radiological studies have revealed an unsuspected high prevalence of urological lesions in young persons, and the occurrence of such lesions shows good correlation with data on egg output. These recent cross-sectional studies have led to a revision of thinking on the health significance of infection with *S. haematobium* in areas of East and West Africa where it had been assumed that the disease was essentially benign.

There have been few recent additions to knowledge of the public health significance of infections produced by *S. mansoni* and *S. japonicum*. However, the Committee desires to re-emphasize the fact that intestinal schistosomiasis is a major cause of morbidity and mortality in areas of high endemicity. A few longitudinal studies designed to assess the significance of infections with *S. mansoni* or with *S. japonicum* are in progress; such investigations are difficult but highly important.

The Committee cannot over-emphasize the importance of carefully controlled longitudinal studies designed to assess the long-term effects of schistosomiasis on human populations. All possible support should be given to such studies now in progress, and their number should be increased.

Efforts to standardize the collection and reporting of survey data should be continued. Simpler techniques for assessing the clinical significance of schistosomiasis are needed.

4. CONTROL

4.1 General principles

Although control programmes have had a measure of success in a number of endemic areas, they have not been as successful as they might have been because of lack of adequate epidemiological information, insufficient understanding of the clinical and economic importance of the disease, inadequate application of control methods, shortage of staff and money, and failure to understand the quantitative inter-relationships between the various factors involved in transmission. Recently developed mathematical models have indicated more clearly the gaps in our knowledge of the last of these areas.

4.1.1 *Objectives of a control campaign*

The objectives of a control programme depend not only on the nature and extent of the problem but also on the availability of funds and trained personnel. In some areas, such a programme may have the very modest objective of limiting the spread of the infection. In other conditions of ecology, budget, and manpower, a reduction in morbidity may be all that can reasonably be sought. In more favourable circumstances the aim may be a significant reduction in transmission, resulting in reduced morbidity, severity, and prevalence. Finally, in optimum circumstances and in limited areas, eradication may be feasible. Before a control programme is launched one of the above objectives must be chosen.

4.1.2 *Feasibility of control*

If it is decided that a particular schistosomiasis control programme is desirable, detailed feasibility studies must follow at once. The gathering of information in an area where schistosomiasis occurs, and the subsequent organization and execution of a control programme, should take place in a logical series of steps. This applies to both the technical and administrative aspects of the programme. The nature of the procedures to be adopted will depend greatly on the data assembled during surveys of the distribution, prevalence, and intensity of infection and of

the species, distribution, and bionomics of the molluscan intermediate host or hosts.

4.1.3 *General considerations*

In many tropical regions, the human population is increasing rapidly, and large areas of previously unused land are being settled. Such circumstances involve a real danger of increasing the prevalence, intensity, and geographical extent of schistosomiasis; this danger is quite independent of irrigation or reclamation works. A further source of danger is the increasing population movements resulting from improved roads, greater mechanization, faster transport, and increased job opportunities due to industrial and agricultural development. Normal nomadic movements, military operations, and pilgrimages have a similar effect. It is almost impossible to control the spread of the disease under some of these conditions.

Most soil and water development schemes in endemic areas lead to an increase in the prevalence and intensity of schistosomiasis, since adequate precautions are seldom taken and control measures are rarely initiated at an early stage. In rare cases, however, careful initial planning and subsequent use of suitable agricultural methods and strict water management have reduced snail habitats and the prevalence of disease.

In arid endemic areas, the intermediate hosts and man are limited in their distribution, and ecologic and climatic conditions often sharply limit the length of the transmission season. The introduction of water into such areas often opens them up for invasion by both snails and people. The resulting association almost invariably allows introduction and spread of snail-borne diseases of man and livestock. When water is supplied to areas where foci formerly occurred only occasionally, the following changes usually take place: (1) the area becomes capable of supporting greater snail and human populations, (2) the number and extent of sites where transmission of snail-borne disease can occur are greatly increased, and (3) the length of the period of such transmission is extended. Such changes result in increased prevalence and intensity of infection. In some poorly-drained areas intermediate hosts may be very common, but the characteristics of their habitats tend to limit human contact. In such areas reclamation by drainage may greatly reduce the extent of the snail habitats. At the same time, however, this advantage may be offset by increased human activities in the area and correspondingly greater contact with the snail colonies that remain in the drains, canals, and other residual habitats. All such irrigation and reclamation schemes in potential schistosomiasis areas should be studied very carefully from the earliest planning stages, and wherever possible the appropriate control measures should be taken.

4.1.4 *Organization and supervision*

The administrative aspects of a schistosomiasis control programme are as important as its technical aspects.

The characteristics of a good plan are that it should be based on a clearly defined objective, should be simple, and should provide for a proper analysis and classification of actions. Standards must be set so that performance can be assessed both qualitatively and quantitatively. The plan should be flexible and should use available resources to the utmost.

The policy or plan having been decided upon, the next step is organization, where administration perhaps makes its greatest contribution. Three fundamental tenets of modern management are applicable to the administration of schistosomiasis control programmes: the quality of the working force is the most vital factor in success; initiative is to be encouraged; and the raising of morale in the working group is more important than the imposition of rigid discipline.

In setting up a control organization the principle of centralized direction and decentralized activity in the field should be followed. The organization should be established at three levels: directional staff at the headquarters of a province, supervisory staff at intermediate divisional level, and staff at the periphery. As far as possible, technicians should be trained so that they can work both in the field and in the laboratory.

Each peripheral unit should have a pre-determined itinerary and area of work. Details of work should be clearly defined, leaving no ambiguity or room for avoiding responsibility. It is an advantage to have separate evaluation units, distinct from the control units.

An "operational manual" in a language appropriate to the local situation is of great value. Such a manual should contain detailed information on the executive and technical organization of the campaign and should be revised from time to time so that improved procedures and techniques can be included.

Evaluation procedures must be built into the plan as an essential element and maintained continuously. Evaluation is not an end in itself, or a means to justify past performance, but rather a powerful tool for improving and reorienting the development of the campaign.

The Committee also feels that an integral part of any control scheme should be an educational campaign to promote public acceptance of the programme by informing the people of the direct benefits it will bring to them.

4.2 **Snail control**

Two methods for snail control have been widely used: chemical control and modification of snail habitats. A third method, biological

control, has had only limited use. Although there is a great deal of evidence to suggest that snail control is the most effective single measure for reducing schistosomiasis, it is now generally accepted that successful control of the disease in many foci can be achieved only by a carefully selected combination of measures. Similarly, once the place of snail control in a particular programme has been determined, the extent to which each available control technique is used depends upon detailed assessment of the local ecology of snail habitats.

4.2.1 *Chemical control*

Since publication of the third report of the WHO Expert Committee on Bilharziasis,¹ more detailed information has been received, and the advantages and disadvantages of various "available"² molluscicides are summarized in the accompanying table. The properties of selected "available" and "candidate" molluscicides are summarized in the Annex.

4.2.1.1 "*Available*" molluscicides

On the basis of effectiveness, completeness of evaluation, and commercial availability, niclosamide (Bayluscide), NaPCP, and copper sulfate may be classified as "available" molluscicides. It is difficult to state the advantages and disadvantages of these molluscicides satisfactorily because their adequacy depends not only upon the particular formulations that are used and the way they are applied, but also upon the objectives of the control programme and the condition of the snail habitats. Furthermore, commercial availability depends upon a number of factors—for example, it has proved difficult to provide a safe, inexpensive container for acrolein³ (Aqualin), an otherwise impressive molluscicide/herbicide.

*Niclosamide*³ (Bayluscide) is currently recognized as the molluscicide of choice. Its concentration \times time (ppm \times h) values are similar in laboratory and field tests against aquatic snails in both still and flowing water. The ppm \times h values are about the same for 24- and 1-hour exposures, but efficiency is less with 6-hour exposures. Within this range, therefore, the ppm \times h values do not appear to be constant.

Niclosamide is effective against amphibious oncomelanid snails, but its cost-efficiency index against such snails has not been adequately determined in comparison with NaPCP. In laboratory tests when used at the LC₉₀ it is stable for 4-6 days, but it is probably less stable under field conditions. This constitutes a problem in natural streams where

¹ *Wld Hlth Org. techn. Rep. Ser.*, 1965, 299.

² The term "available", as used in this report, implies commercial availability in a suitable formulation, and effectiveness and completeness of evaluation as a molluscicide.

³ Name recommended by the International Organization for Standardization (ISO).

ADVANTAGES AND DISADVANTAGES OF SELECTED "AVAILABLE" MOLLUSCICIDES ¹

Molluscicide	Advantages	Disadvantages
Niclosamide (Bayluscide)	Highly toxic to snails and eggs; safe to handle and use; probably the cheapest chemical per unit volume of water treated; does not upset the biota as much as some compounds	Difficult to formulate; in certain types of habitat available formulations do not disperse effectively
Copper sulfate (and other copper compounds)	Active at a low pH; somewhat less toxic to fish than other molluscicides; safe to handle	Absorbed by soil and organic material; ineffective at a high pH; corrosive to equipment; of variable toxicity to snails and their eggs under field conditions
Sodium pentachlorophenate	Kills both snails and their eggs; excellent penetration downstream has been achieved; widely used for other purposes and so not dependent on a molluscicide "market"	Irritating and potentially dangerous to the handler; required dose relatively high compared with new molluscicides; activity may be reduced by bright sunlight

¹ Reproduced, with slight modifications, from *Bull. Wld Hlth Org.*, 1965, 33, 567.

impoundments occur frequently, because the chemical is inactivated before it has been carried an adequate distance downstream. However, if the wettable powder is added directly to all impoundments along a stream, these serve as reservoirs in lieu of drip systems. The latter tend to be impractical in natural watersheds because of the multiplicity and the characteristics of snail habitats in the headwaters. Niclosamide is stable in storage, but deteriorates to some extent in 2-3 years. Its toxicity to mammals is low and it is not irritating; thus it is especially useful for spraying stagnant water along streams and large swamp areas. Although it is generally biocidal, restoration of the biota occurs rapidly. With 24-hour exposures niclosamide is about equally effective against eggs and other stages of aquatic snails. With 6-hour exposures, however, the effective "dosage" (ppm × h) required for adolescent and mature snails is about twice that required for eggs. Physical and chemical factors in the environment cause only minimal inactivation of niclosamide; however, it shows slight photoinstability, which increases with water hardness. Loss of the molluscicide by physical or chemical adsorption is moderate, and it is not affected by the range of pH values found in most natural waters. In most areas its over-all cost-efficiency ratio is favourable compared with NaPCP.

NaPCP (*sodium pentachlorophenate*) has been tested more extensively than any other molluscicide. It is quite effective under certain conditions and it is commercially available at reasonable cost, but it has

some undesirable properties. It is generally biocidal and its effectiveness against both aquatic and amphibious snails is well-established. Time-concentration studies show that 1- and 6-hour exposures do not give maximum efficiency; better results are obtained with 24-hour exposures, and the use of prolonged low concentrations holds some promise. It is effective against eggs and newly hatched snails but both show increased resistance with age, especially as exposure time is reduced. Laboratory tests have shown NaPCP to be chemically stable for more than 32 days at LC₉₀ concentration, and its stability during storage is adequate. However, sunlight has an adverse effect on its stability, although this effect is reduced in turbid water. Some adsorption of NaPCP by mud has been reported, but this effect does not appear to be serious. At some concentrations, the irritating nature of this molluscicide may cause snails to leave the water and thus avoid lethal exposure. NaPCP can be handled safely only if adequate precautions are taken; careless use of the substance has caused a few deaths. Its application requires strict supervision, which may increase the cost. This applies particularly to the powdered forms; briquettes and other formulations are less hazardous.

Copper sulfate has for long been used as a molluscicide, but it has serious disadvantages. Among these is the fact that field use may require 20-30 times the amount of the chemical shown to be necessary in the laboratory. It is believed to hold promise when used for prolonged periods at low concentrations under conditions of low pH, low dissolved-solid content, low turbidity, and fast water flow. Furthermore, it has been shown to have a prolonged biocidal effect. The drawbacks of copper sulfate are partly compensated for by its low cost.

4.2.1.2 "Candidate" molluscicides

There are a number of candidate molluscicides that have various advantages and disadvantages (see Annex). Three of these—*acrolein*,¹ *paraquat*,¹ and *diquat*¹—are both molluscidal and herbicidal, but none of them can be placed on the "available" list. Acrolein (Aqualin), though highly regarded as a molluscicide/herbicide and extensively used for weed control in irrigation systems, is extremely volatile and is difficult to handle, except by specially trained personnel. Both paraquat (Gramaxone) and diquat (Réglone) are relatively effective at concentrations of 1-5 ppm, but they are costly.

Organo-tin compounds have attracted attention because of their high toxicity for snails and eggs. They are effective when the exposure period

¹ Name recommended by the International Organization for Standardization (ISO).

is 6 or 24 hours, but not when it is 1 hour. Results of laboratory studies of their use at low concentrations for prolonged periods show promise, but this technique has not been tested in the field. Furthermore, the effects of physical and chemical factors upon organo-tin compounds have not yet been determined adequately. Organo-tin compounds have a broad commercial use and their cost is reasonable.

*Dinex*¹ (2-cyclohexyl-4,6-dinitrophenol) has long been recognized as a good molluscicide but it has not gained favour, since NaPCP has a superior cost-efficiency ratio, especially for aquatic snails. On the other hand, *dinex*—unlike NaPCP—is not affected by sunlight. At present it is not in commercial production. Other dinitrophenols are less effective than *dinex*.

N-tritylmorpholine (Frescon) is the most active molluscicide known. However, although it is active against snails upon short exposures, it is inactive against their eggs, and application of the molluscicide for periods of 2-4 weeks at very low concentration may be necessary. Such long exposures kill adult snails and then destroy young snails as they hatch. The chemical has low toxicity for mammals, it is safe to handle, and its cost is said to be reasonable. Studies of the effects of physical and chemical factors upon *N-tritylmorpholine* have not been reported.

Several insoluble *copper compounds* have been tested. It appears, however, that the active agent is the Cu^{++} ion, in which case such compounds may have the same disadvantages as copper sulfate. Cuprous oxide has attracted attention because of its residual effect, but thus far no field test of this compound has been reported. One favourable field trial of copper carbonate against human schistosome vectors has been reported, but the compound has not received further attention.

Carbamates have been reported to be active against *Oncomelania* snails, to some degree against *Bulinus* in Africa, and to a lesser degree against *Biomphalaria glabrata* in Brazil.

3-trifluoromethyl-4-nitrophenol (TFM), a compound used extensively for control of lampreys in the USA, has been discovered to be fairly toxic to *Biomphalaria glabrata* and nontoxic to a wide variety of fish. This compound is available commercially and may have value for snail control in fish ponds.

Recent studies on the molluscicidal properties of the Ethiopian herb, *Phytolacca dodecandra*, or Endod, have shown promising results. Further work of this nature should be encouraged.

¹ Name recommended by the International Organization for Standardization (ISO).

4.2.1.3 *Methods of employing molluscicides*

Because there are many different types of snail-host habitat, methods of molluscicide application must be carefully selected. Habitats can be divided into four main types, as described in the WHO publication *Snail Control in the Prevention of Bilharziasis*.¹ The nature of the habitat largely dictates the selection of the molluscicide and its method of application, although the efficacy of the molluscicide and the cost of the operation must, of course, also be taken into consideration.

In the application of molluscicides it is desirable that the chemical be uniformly distributed throughout the entire body of water so that all snails and their eggs will be killed. Since it is not practical—and sometimes impossible—to secure thorough mixing of chemicals in natural bodies of water by mechanical means, natural forces must be relied upon to ensure uniform distribution. These natural forces include wave action, thermal or gravity currents, and diffusion (turbulence or molecular). Understanding of the ways in which these forces contribute to the dispersal of molluscicides is desirable.

If the molluscicide is properly dispersed in still water, there is usually ample opportunity for it to come into contact with snails. Under these circumstances the activity of the chemical is usually prolonged. In running water, on the other hand, the chemical is swept downstream at a rate that depends on the velocity of flow and the profile of the stream. Furthermore, in meandering streams the molluscicide may not penetrate stagnant or disjunct pools or eddies in lethal concentrations. The dispersal of molluscicides in irrigation canals also varies, depending on the type of channel, the amount of vegetation present, and other factors.

Detailed knowledge of the duration of activity of a molluscicide is essential, especially when it is used in flowing water, where dilution may lead rapidly to loss of activity. It has been reported that certain molluscicides are broken down by bacterial action, but many other factors also cause loss of activity.

If a molluscicide is added to a stream at a place of high turbulence, uniform distribution in the water results. As it moves downstream, however, the molluscicide "wave" is diluted at both ends. It is difficult to calculate the loss of efficacy in terms of time or distance downstream, and such loss must usually be determined experimentally. In the case of a very short stream or irrigation canal, a single application of molluscicide may be sufficient to maintain an adequate concentration of the chemical throughout its length. However, when dealing with flowing waters in which snail infestation occurs over a considerable distance, it

¹ *World Health Organization: Monograph Series*, No. 50 (1965), pp. 1-72, 80-84.

is usually necessary to add more molluscicide at the point where the concentration of originally applied chemical is no longer lethal. Various colorimetric techniques have been devised for the measurement of molluscicide concentration, but for the newer compounds bioassay methods must be used.

Judgement must be exercised in selecting the "dosage" to be applied in any given situation. For treatment of a short stream that discharges into a large river, there is no reason to use a $\text{ppm} \times \text{h}$ value greatly in excess of the optimum, because there is no time for the chemical to deteriorate appreciably before it is completely inactivated by dilution. If longer reaches of a stream or canal are to be treated, it may be more economical to use higher initial concentrations and fewer downstream "booster" applications.

Two general strategies for snail control are in current use: local control and area control. Local control is valuable in endemic areas where transmission occurs only in limited foci, while area control may be the only practical approach where transmission is a problem throughout a watershed or an irrigation system.

A control programme aimed at limited transmission foci requires detailed epidemiological study to pin-point the important foci of transmission. Once these have been found, the regular application of a molluscicide is started, applications being repeated whenever snails reappear. Since snails can reinfest treated zones from surrounding untreated areas, periodic mollusciding must be continued.

Control of an entire watershed or irrigation system is initially more difficult than local control, but it has the advantage that fewer applications of the molluscicide may prove effective. It is also possible that the snails may eventually be eradicated, in which case mollusciding operations throughout the area can cease, except in any residual foci that may be revealed by surveillance.

In area control, snail habitats must be treated in a rigid sequence. In watersheds the sources of all streams, which may be hard to reach and treat, must first be freed of snails; habitat modification by drainage or other methods may be necessary. The watershed is then treated systematically from the top down. Irrigation systems are usually treated by introduction of molluscicides at the water intakes, ensuring eventual penetration of the chemicals to the entire distribution system. It may be necessary to treat drains separately.

Concern aroused in recent years by the extensive and sometimes injudicious use of insecticides led the Committee to consider related problems concerning the use of molluscicides. It was agreed that at present molluscicides have an essential role in health and resource development programmes, but that the biocidal aspects of their wide-scale use must be investigated.

4.2.2 Control by modification of snail habitats

This subject was fully reviewed in 1965.¹ The Committee noted the serious lack of new methods for the control of snails by habitat modification and felt that this subject deserves attention.

4.2.3 Biological control

The second report of the WHO Expert Committee on Bilharziasis² took a conservative view of the prospects for biological control of snails. Biological control deserves continued study; all possible dangers should be considered, and carefully controlled experiments should be conducted before biological agents are introduced into new areas.

The literature contains numerous incidental observations on the harmful effects of various predators, parasites, and competitors on the intermediate hosts of the human schistosomes. The destruction of aquatic plants by biological means can also have a marked indirect effect on snail populations. A list of the organisms affecting snails directly or indirectly would include species of bacteria, fungi, protozoa, helminths, annelids, arthropods, molluscs, amphibia, fish, birds, and mammals. None of these organisms has been fully evaluated as a snail-controlling agent in the laboratory or in the field.

Extensive and varied studies on the biological control of one of the intermediate hosts of a human schistosome have been made in Puerto Rico and the neighbouring island, Vieques. Laboratory studies have shown that the ampullarid snail *Marisa cornuarietis* affects populations of *Biomphalaria glabrata* in at least two ways: (1) it competes with them, being a voracious feeder; and (2) it consumes the egg masses and the young of *B. glabrata*. The judicious use of chemical control and the introduction of *M. cornuarietis* into *B. glabrata* habitats in Vieques Island have practically eliminated the latter snail and there is evidence that the transmission of schistosomiasis has ceased. *M. cornuarietis* is now used routinely in Puerto Rico as part of the schistosomiasis control campaign.

Some time after the introduction of *M. cornuarietis* into Puerto Rico another exogenous snail, *Tarebia granifera* (syn. *Thiara (Melanoides) granifera*) appeared in a few habitats and spread rapidly into many watersheds. There is evidence that this snail can also displace *B. glabrata*, and it is believed to be one of the factors responsible for the gradual decline in the prevalence of schistosomiasis in children in the Caguas Valley.

No significant ill-effects have been observed as a result of the introduction of these two snails to Puerto Rico. However, certain species of *Tarebia (Thiara)*, among which is *T. granifera*, are the intermediate hosts of the human lung fluke, *Paragonimus westermani*, in the Orient. Their

¹ World Health Organization: *Monograph Series*, No. 50 (1965), pp. 63-122.

² *Wld Hlth Org. techn. Rep. Ser.*, 1961, 214.

introduction into new areas cannot, therefore, be recommended. *M. cornuarietis* is not known to serve as an intermediate host for any important parasites, and all attempts to infect it with trematodes that affect man and domestic animals have failed. It is known that the snail is a pest in watercress beds but it has been reported that it does not affect rice. The latter finding requires confirmation. Meanwhile, the dangers of introduction of *M. cornuarietis* into new habitats are not well understood. Its introduction into endemic areas for the purpose of reducing populations of schistosome intermediate hosts should be considered only after due attention is given to possible adverse consequences.

The observations described above have encouraged the belief that biological control can be used in combination with other measures. However, it is not at all certain that *M. cornuarietis* would be useful in other endemic areas, in other types of habitat, and against other species of intermediate hosts.

There is some evidence that the "shellcracker" fish, *Lepomis microlophus*, may be of value in the control of snails in Puerto Rican fish ponds.

In Kenya, extensive field trials have been conducted over a 10-year period of the usefulness of a snail-eating fish, *Astatoreochromis alluaudi*, in the control of *Biomphalaria* and *Bulinus* in ponds and borrow-pits. The results have shown some promise, and it is recommended that a careful assessment be made of this technique. It has also been reported that the introduction of *Gambusia* into snail habitats in the Sahara caused a marked reduction in intermediate host populations.

Other organisms of potential value for biological control are at present receiving some attention, but their value is even less well-established than that of the agents mentioned above. They include *Limnogeton fieberi* and the larvae of sciomyzide flies. It is obvious that a great deal more laboratory and field research on these and other organisms is required before they can be considered for general use. Until information from such studies is available, it is impractical to discuss the advantages and limitations of biological control measures. It is evident, however, that successful biological control would offer economic advantages and decrease the need for highly specialized personnel.

4.2.4 Cost analysis

The Committee considers that cost-estimate and cost-analysis information is of great importance. Cost analyses are at present based on over-all per capita cost, cost per protected inhabitant, cost per unit volume of water treated, cost per acre, cost per length of water course treated, or a ratio of two such factors. None of these is entirely satisfactory. Furthermore, it is always necessary to define the aims of such analyses—for example, the planning of a new control project or the evaluation of an existing one. The comparison of programmes in different

areas may be extremely difficult, if not impossible, because of inherent differences between the areas. The Committee is of the opinion that the complexity of this problem usually makes it necessary to obtain expert assistance.

4.3 Chemotherapy

The third report of the WHO Expert Committee on Bilharziasis¹ reviewed the role of chemotherapy in the control of schistosomiasis, and the available schistosomicidal drugs have been described in a recent report of a WHO Scientific Group.² Information on a few new schistosomicidal drugs is now available.

Ambilhar, a non-antimonial, nitrothiazole derivative, was introduced recently for the oral treatment of schistosomiasis. Initial trials indicate that it is effective, and high cure rates have been recorded, especially in patients infected with *S. haematobium*. It is too early to assess the toxicity of this drug accurately; however, serious side effects, especially transient neuro-psychiatric disturbances, have been recorded. There is some hope that this drug or some analogue of it may be of value in control programmes but a decision must await a careful assessment of its toxic effects.

Other new drugs, such as tris (*p*-aminophenyl) carbonium pamoate (TAC pamoate) and trichlorfon, are under trial but their possible role in control programmes must await further information.

In view of the pressing need for safe and effective schistosomicidal agents, the Committee recommends that the search for new drugs should be continued.

4.4 Environmental control

The third report of the WHO Expert Committee on Bilharziasis drew attention to the role that public health services and health education should play in the control of schistosomiasis. The present Committee noted the recent demonstration in South Africa that in certain situations schistosomiasis could be controlled satisfactorily by the reduction of human contact with cercaria-infested water.

4.5 Evaluation of control programmes

4.5.1 General principles

Continued evaluation must be an integral part of a control programme and form the basis for improvement and re-orientation. The

¹ *Wld Hlth Org. techn. Rep. Ser.*, 1965, 299, 45.

² *Wld Hlth Org. techn. Rep. Ser.*, 1966, 317.

essential elements that must be evaluated are progress towards achievement of the goal, cost, and public acceptance. Although the first two of these factors can be evaluated objectively, the third is difficult to measure precisely.

The Committee recommends that a methodology be developed for estimation of the costs involved in control projects and for cost-benefit analysis.

The Committee also feels that an integral part of the evaluation of any control scheme should be measurement of the social and financial benefits that affect public acceptance of the programme.

The efficacy of a control programme is evaluated on the basis of data on the degree of infection in man, the disease in man, and other factors before any control work is done. The control programme is then instituted and from time to time thereafter the same factors are measured by exactly the same methods on the same population groups. In this way one obtains strictly comparable, consecutive records that can reveal—in a reliable, quantitative way—changes brought about by the control measures used. Usually the measurements used to determine the efficacy of a control programme must be made separately and for the sole purpose of evaluation. Other data collected in the pre-control period may also be useful in making an evaluation but are often insufficient, in themselves, for that purpose.

Natural fluctuations occur in the prevalence, incidence, and intensity of schistosomal infection in human and snail hosts from one season to another and from year to year, and should be taken into account when the effects of a control programme are evaluated. If valid conclusions are to be drawn, data collected over several years may be necessary.

Suitable reference areas should be left untreated for the purpose of comparison; by this means, adjustment for the influence of factors unrelated to applied control measures is made easier.

Methods for evaluating the efficacy of schistosomiasis control can be divided into two groups : (1) those that measure the effect of control on human infection and disease, and (2) those that provide indirect evidence of control.

4.5.2 *Effects of control on human infection*

The institution of control measures should result in a detectable change after a suitable period of time, in (1) the prevalence of infection, (2) the incidence of infection, (3) the intensity of infection, and (4) the severity of the symptoms of the disease. Study of one or more of these changes should, therefore, reveal the efficacy of a control programme. It is suggested that study of the following would be useful in evaluation :

- (a) over-all prevalence of infection;
- (b) age-prevalence in children, and age of peak prevalence;

- (c) incidence of infection in children;
- (d) changes in intensity of infection;
- (e) injury to infected persons.

The study of changes in the incidence and intensity of infection in new cases provides a more sensitive indication of change in transmission of the disease than does the study of prevalence. A longitudinal study is a useful procedure for this purpose. In this connexion, the establishment of a suitable method of identifying individual persons at successive surveys is of great value.

The intensity of infection should be assessed quantitatively. A satisfactory egg-counting technique has been developed for *Schistosoma haematobium*, but the Committee considers that there is need for the development of simple egg-counting techniques applicable to *S. mansoni* and *S. japonicum*.

Certain techniques, such as bladder biopsy, liver biopsy, and special radiological examinations, that are valuable for the clinical study of individual patients, are too hazardous for the routine evaluation of control programmes.

There are few satisfactory objective clinical criteria for assessing the effect of control. Data on spleen and liver size and on haemoglobin levels may be of value in areas where *S. mansoni* and *S. japonicum* are prevalent, but better criteria are urgently needed. With *S. haematobium* infections haematuria is of some value as a criterion, but so far no techniques have been developed for measuring the quantity of blood in the urine.

In many areas where schistosomiasis exists, autopsies are performed only on a highly selected group of cadavers that are not representative of all the deaths that occur in a given community. Nevertheless, some consideration should be given to the use of autopsy material, such as liver tissue for egg counts, in areas where a control programme is associated with a central hospital where enough such material can be collected.

4.5.3 *Indirect evidence of control*

Although the true measure of the efficacy of a control programme must be in terms of human infection, indirect evidence of progress towards the control objective may have some value, especially if such evidence can be obtained more rapidly. Study of the following may be of value :

- (a) snail populations;
- (b) the prevalence of specific schistosome infections in snails;
- (c) cercarial density in natural water;
- (d) schistosome and other trematode infections in animals.

Method (c) may be useful for detecting cercariae released by snails that are not revealed by routine sampling. However, this technique has serious drawbacks in areas where other schistosomes of mammals are prevalent. Indirect evidence of a reduction in transmission of human schistosomes can sometimes be obtained from data on the prevalence of schistosomes and other trematodes that infect wild or domesticated animals.

5. TECHNIQUES

5.1 Parasitological techniques

The Committee considered some of the techniques applicable to the study of schistosomiasis and to evaluation of control programmes. Several general considerations were borne in mind. For example, any technique should be evaluated in terms of its sensitivity, specificity, and repeatability. The final choice of technique depends upon its practicability within a given area and upon the major objective of the study.

In this connexion, the report of the third WHO Expert Committee on Bilharziasis emphasized the desirability of using egg-counting techniques. In the interim, relatively new and promising techniques have been described, and these deserve special comment.

5.1.1 *Methods for the quantification of worm burdens*

Special care must be taken to ensure that the phase of peak egg output, giving the most reproducible results, is the one sampled. There is little indication as to the optimum time for collection of faecal samples. However, investigations of *S. haematobium* infections have established the fact that maximum egg output in the urine occurs near midday; the optimum time for collection of specimens is, therefore, between 10 a.m. and 2 p.m. Ideally, however, 24-hour urine samples are desirable for studies of total egg excretion.

Urine specimens: Filtration of a measured sample of urine followed by a count of the eggs retained on the filter has been shown to be a sensitive method that gives reproducible results. In this relatively new technique, a measured sample of urine is passed by suction through a filter paper held on a porous surface, usually by a metal ring that restricts the area through which the urine passes. The filter paper is then treated with gentle heat or formalin to kill the eggs, wetted with fresh, aqueous ninhydrin solution, and again gently heated until dry. The dye causes the embryos to turn a distinctive purple, the shape of the egg being unaffected. The eggs are counted by placing the dampened filter paper under a suitable counting grid on the stage of a low-power microscope.

Faecal specimens: A recently described filtration technique makes more accurate egg counting possible. A measured amount of faeces, preferably from a 24-hour sample, is diluted in water or preservative, clarified by screening, and drawn through a filter paper. Some of the residual faecal debris and all the eggs are left on the paper, which is then treated in the same manner as the paper used for collection of eggs from urine. If a suspension of 100-200 mg of properly prepared faeces is passed through a filter paper 7 cm in diameter, there is no interference from debris and the eggs can be seen clearly and identified by their characteristic morphology.

Several modifications of the simple smear method have been introduced for surveys of prevalence of helminth infections. The method—extensively used in Japan—of combining glycerol with a dye in a preparation mounted under a cellophane cover might be of value in both qualitative and quantitative studies of *S. mansoni* and *S. japonicum*. In Korea a very simple hygienic technique has been developed: the faecal sample is collected in a small polyethylene bag, smeared inside the bag, and examined directly under the microscope. This method has an additional advantage in that expensive slides and cover-slips are unnecessary. The applicability of both these techniques to the study of schistosomes requires study.

Furthermore, the Committee noted that all new methods should be studied in various situations, in which the quantity, consistency, and composition of the faecal specimens may vary widely. It should also be pointed out that if gauze is used to filter faeces during processing, a large proportion of the eggs may be lost.

5.1.2 *Detection of cercariae in natural habitats*

The Committee noted the valuable new information on the epidemiology of schistosomiasis that has recently been obtained from studies of the detection of cercariae in natural habitats. The use of "sentinel" rodents in water has clearly indicated both seasonal and diurnal variation in the risk of infection to such rodents. The assessment of cercarial densities by means of concentration by centrifugation or filtration of water is a promising procedure, the results of which are in general agreement with those obtained by the use of "sentinel" animals.

Quantitative cercaria-detection techniques are in a stage of evolution and further research is necessary to solve the problems involved in the assessment of cercarial densities in turbid natural waters. It should, furthermore, be emphasized that both the "sentinel" animal technique and physical methods of concentrating cercariae may yield false results unless schistosomes that infect man are differentiated from those that do not.

5.1.3 *Detection of worms in man at autopsy*

The Committee noted the valuable technique recently described in the report of a WHO Scientific Group on Research in Bilharziasis¹ dealing with the recovery of *S. mansoni* from cadavers. Such methods provide new and valuable insights into the natural history and pathogenesis of schistosomiasis.

The technique uses perfusion of the liver and the portal tributaries followed by intensive search of the bowel wall. After removal of the viscera, the liver is perfused by pumping water or saline into the vena cava above the renal veins, and the worms are recovered from the cut portal vein. The mesenteric veins are then perfused by retrograde flow, the cannula being introduced successively into the larger mesenteric veins after the mesentery has been separated from the bowel. Finally the intestine is examined visually for worms. The mucosa is stripped away from the sub-mucosa and both layers are searched using a dissecting microscope and transmitted light. The method is laborious but it gives valuable information on the relationship between worm load and tissue and faecal egg densities.

Similar studies on the infections produced by *S. haematobium* and *S. japonicum* are highly desirable.

5.1.4 *Detection of eggs in tissues*

Press preparations will detect both living and dead eggs but the technique is slow, insensitive, and difficult to perform quantitatively. Other techniques may be used to advantage for the collection of qualitative data at autopsy.

It is common practice to use a caustic solution for digesting tissues. Although this procedure gives a clear and easily examined residue, it can destroy immature eggs. More accurate results may be obtained by means of preliminary enzymatic digestion followed by clearing of the residue with a dilute caustic solution before the eggs are counted.

5.2 **Malacological techniques**

Recent studies have emphasized the necessity of careful consideration of the ecology of the area under study and of the objectives of the sampling operation before a sampling technique for quantitative estimation of snail populations is selected.

During the last few years progress has been made concerning the taxonomy of the snail intermediate hosts. A certain degree of stability has been achieved in the generic nomenclature of planorbid intermediate

¹ *Wld Hlth Org. techn. Rep. Ser.*, 1967, 349.

hosts of *S. mansoni* in the Eastern and Western Hemispheres. A recent decision of the International Commission on Zoological Nomenclature gives preference to the generic name *Biomphalaria* over several others that have been suggested. In this report the generic name *Biomphalaria* is used in place of its synonyms *Australorbis* and *Tropicorbis*.

Identification, collection, fixation, dissection, and other malacological techniques have been described in a recent document.¹

For the identification of snails collected in the field, methods based on criteria other than morphology have been attempted. Electrophoresis studies of egg proteins have shown specific differences in the latter, and are probably more promising for the differentiation of species than similar studies of snail tissues and haemolymph proteins.

Serological techniques have been used to compare the precipitating activity of the various haemolymph antigens in the presence of specific snail antisera. Genera and a few congeneric species have been differentiated by gel diffusion methods, but the application of this approach needs further study. However, such techniques could be of practical use as antigens from snails crushed on filter paper could be sent to a central laboratory for processing and identification.

Chromosome studies of several taxonomic groups of snails have been proved to be of value for identification only in the case of some bulinid snails that are intermediate hosts of *S. haematobium* in Africa. There is some evidence that susceptibility of certain bulinids to the schistosomes is associated with polyploidy, but this has yet to be confirmed by further investigation.

6. RECOMMENDATIONS

6.1 Direct support of control operations

The Committee was of the opinion that adequate techniques are available for control of the disease in many endemic areas. Therefore, the Committee feels that WHO should endeavour to increase its support for national control programmes. This assistance should emphasize training of personnel since this is the most serious shortage at the present time.

Eventually, when national control programmes have achieved success and enough trained personnel are available, it may be possible to consider regional control programmes or even a world-wide control programme.

¹ *A guide for identification of the snail intermediate hosts of schistosomiasis in the Americas*, Washington, D.C., PAHO/WHO (in press).

The Committee also urges that all possible encouragement and help be given to countries that have not yet started control measures, with a view to extending control to as many endemic areas as possible. This assistance, if requested by national governments, should be available from the earliest planning stages. In some countries, long-established control programmes using rather out-dated methods would benefit greatly from assistance in the improvement of techniques. In other countries there is an urgent need for the extension of existing programmes.

6.2 Problems of recruitment, training, and staffing

There is an extremely serious lack of personnel trained in the various disciplines required for schistosomiasis control. This lack is not confined to professional levels, but extends to auxiliary staff also, and it is a limiting factor in the extension of control.

The Committee therefore recommends that WHO should consider the possibility of recruiting and training sufficient personnel to permit the provision of large-scale technical assistance to a considerable number of national control programmes.

Such a recommendation undoubtedly creates many difficult problems. To attract professional personnel of a high calibre requires a career structure offering reasonable prospects of tenure; for some years to come, it will be impossible for many countries to offer such conditions. In addition, many countries with urgent schistosomiasis problems will for a considerable time be unable to supply such personnel from amongst their own nationals, and will have to rely on staff recruited elsewhere. Nevertheless, the Committee feels that WHO should take the lead in finding solutions to this problem.

There should be three principal types of training :

(a) Advanced post-graduate professional training, preferably carried out in established schools of tropical medicine and public health, where suitable facilities exist, for epidemiologists, parasitologists, malacologists, and engineers. The institutes where such training is conducted should establish close associations with suitable field centres where practical instruction and experience are available.

(b) Training in special inter-regional schistosomiasis training centres. Such centres could be located in WHO-assisted project areas that would provide opportunities for field demonstrations.

(c) In-service training of auxiliary personnel. This is best carried out locally, but should be carefully planned and executed under the supervision of senior staff.

6.3 Research

The following areas of research are considered to be of sufficient importance to warrant special attention.

6.3.1 *The human host*

- (a) Better direct and indirect methods of diagnosis and measurement of the intensity of infection.
- (b) Improved methods of measuring the severity of disease in man.
- (c) Safer and more effective antischistosomal drugs.
- (d) The degree of protection to human schistosome infection afforded by previous exposure to animal schistosomes.
- (e) The effect of nutrition and other factors on clinical manifestations.
- (f) The correlation of egg counts with the number of worms recoverable at autopsy and with pathological findings. Studies of *S. haematobium* and *S. japonicum* are needed, and further study of *S. mansoni* would be desirable.
- (g) Human habits in relation to contact with water.

6.3.2 *The parasite*

- (a) The differentiation of schistosomes occurring in man from related species in other animals.
- (b) The "scanning" ability of miracidia.
- (c) Detection of cercariae and estimation of their density in natural waters.

6.3.3 *The molluscan intermediate host*

- (a) More precise methods for the determination of species.
- (b) Snail-host/parasite relationships, particularly mechanisms of susceptibility.
- (c) Distribution in Africa.
- (d) The snail hosts of the *S. japonicum*-like species that infect man in Thailand and Laos.

6.3.4 *Control methods*

- (a) Methods of preventing the introduction of snails into newly established irrigation systems.

- (b) New design and operational techniques to prevent transmission in irrigation schemes proposed for endemic areas.
- (c) Simplification of methods for the application of molluscicides.
- (d) New and more effective molluscicides, especially an effective non-piscicidal compound.
- (e) The value of biological control.

6.3.5 *Public health implications*

- (a) The impact of schistosomiasis on the economic and social structure.
- (b) The disability produced by infection.
- (c) The role of lower animal reservoir hosts in the transmission of infections.

6.4 Terminology

A Joint OIHP/WHO Study Group on Bilharziasis in Africa,¹ held in Cairo in 1949, recommended that the name "bilharziasis" be used to designate the disease caused by species of schistosomes infecting man. WHO has so far followed this recommendation. However, the name "bilharziasis" has been generally adopted only in parts of Africa. The Committee therefore recommends that the terms "bilharziasis" and "schistosomiasis" be regarded as interchangeable, but that WHO should consider official adoption of the term "schistosomiasis" for the disease in man as well as in animals.

The Committee also suggests that to avoid confusions in terminology a glossary be included in the manual on the epidemiology and control of schistosomiasis at present being prepared by WHO.

¹ *Wld Hlth Org. techn. Rep. Ser.*, 1949, 17.

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Annex *

MOLLUSCICIDES AND THEIR PROPERTIES ^a

Common and/or trade name	Physical form of technical material	Active ingredient	Solubility in water	Toxicity of technical material ^b				Stability of technical material affected by :					Handling qualities		Formulations	Field dosage		Range of application
				Snail LC ₅₀ , ppm × h	Snail eggs LC ₅₀	Herbicide activity	Rats, acute oral LD ₅₀ , mg/kg	Ultra-violet light	Mud, turbidity	pH	Algae, plants	Storage	Safe	Simple		Aquatic snails (ppm × h)	Amphibious snails on moist soil	
Aqualin ^c (acrolein ^d)	Liquid		22 % w/w 20°C	30-75	15-24	Yes ^e	30-40	?	Yes	Yes	Yes	Yes	No	No	86 % acrolein volatile liquid	75-100 ppm		Flowing water where control of submerged weeds also necessary
Bayluscide (niclosamide ^d)	Crystalline solid	Ethanolamine salt of 2',5'-dichloro-4'-nitrosalicylanilide	230 ppm	5-8	2-4	No	5000	Yes ^f	Normal	Optimum 6-8	No	No	Yes	Yes	Wettable powder containing 70 % active ingredient	4-8	0.2 g/m ²	Flowing and static water
Carbamates e.g., zinc dimethyl-dithiocarbamate	Amorphous solid		65 ppm	50	50-100	No	1400	?	No	?	No	No	Yes	Yes	(1) Granules 50 % + 50 % CaCO ₃ (2) Micronized powder (90 % active ingredient)	10g/m ² 5 g		Where killing of fish is undesirable
Copper compounds e.g., copper sulfate	Crystalline solid		32 %	20-100	50-100	Yes ^g	?	No	Yes	Yes	Yes	Yes	Yes	Yes	Crystals of CuSO ₄ ·5H ₂ O	20-30 ^h		Static and flowing water
(2) insoluble e.g., cuprous oxide	Amorphous solid		Insoluble	7-100	50-100	No	2000	No	Yes	Yes	Yes	In part	Yes	Yes	Powder	60 ^j	— ^k	Static water where killing of fish undesirable

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