Report

Inter-country Meeting on Strategies to Eliminate Schistosomiasis from the Eastern Mediterranean Region

Muscat, Oman
6-8 November 2007
Schistosomiasis (intestinal and/or urinary) has been known to be endemic in 14 of the 23 counties of the Eastern Mediterranean Region (EMR) since a long time. Recent years have seen a notable decrease/drop in the prevalence and morbidity of the disease in many of these endemic countries, some of which may have reached elimination of schistosomiasis specially those endemic with the urinary form of the disease. For instance, the overall prevalence of the disease in Egypt was estimated to be about 40% in 1967 before the national control program started. In 2006, due to the application of different control measures, the overall prevalence fell down to <3%. However, there are still “hot spot” transmission foci with prevalence rates of about 10%. Therefore, lack of sustainability of well structured prevention/control/elimination programs could lead to emergence or resurgence of the controlled disease. In general, emergence or resurgence of schistosomiasis could be a result of changes in public health policy, demographic and societal changes, and diversion of financial support. The China experience is a good practical example demonstrating that relaxation of control measures consequent to achieving a success could result in resurgence of the disease. Following the end of the World Bank loan for the China national schistosomiasis control programme in 2000, the number of infected cases has significantly increased in 2003. Therefore, representatives from the China control programme were invited to actively participate in different meeting sessions and to contribute their knowledge.

Control/elimination efforts in EMR countries have driven the status of schistosomiasis to a turning point. Except Somalia, Sudan and Yemen, all other endemic countries either became of low endemicity or reached disease elimination. Since there are no guidelines endorsed by WHO for elimination of schistosomiasis, the challenge is to verify lack of active transmission in countries claimed elimination and to device strategies, possibly based on new approaches, to direct countries with low endemicity towards elimination. The Regional Committee for the EMR in its 54th session (October 2007) adopted a resolution (EMR/RC54/R.3) calling upon member states to “Sustain successful control activities in low-transmission areas in order to eliminate schistosomiasis and soil-transmitted helminth infections as a public health problem, and to give high priority to implementing or intensifying control of schistosomiasis and soil-transmitted helminth infections in areas of high transmission while monitoring drug quality and efficacy”.

The Inter-country meeting on strategies to eliminate schistosomiasis in low endemic countries of the EMR was held at a moment of momentum. The meeting aimed to bring managers of schistosomiasis control programs, succeeded to bring schistosomiasis down to low endemicity, together with relevant research experts to review the current situation of the schistosomiasis programmes in low endemic countries of the EMR; to define and adopt strategies for the elimination of schistosomiasis adapted to country situations; and to identify priority control oriented research needed and to develop Coordinated Regional and Country plans.

In arranging the meeting program, sessions were devoted to study, in depth, confronting challenges. Getting rid of the last cases to reach zero incidences is a major task that may require methods tailored to satisfy country situation. As the epidemiological picture of schistosomiasis would vary from one endemic country to another, methods/strategies which may prove successful in some areas may need to be modified or supplemented in order to make progress towards elimination. Other possible decisive factors opposing elimination were also discussed. For instance, certain wild animals have been found, in particular countries, naturally infected, however, their role as reservoir hosts remains to be explored and evaluated.
Executive summary

Infection with two schistosomes species, *Schistosoma haematobium* and *S. mansoni*, is known to cause humans schistosomiasis. In the last decade, the disease was endemic in several countries of the Eastern Mediterranean Region (EMR). *Schistosoma haematobium* existed in 14 EMR countries: Djibouti, Egypt, Iran, Iraq, Jordan, Lebanon, Libya, Morocco, Saudi Arabia, Somalia, Syria, Sudan, Tunisia, and Yemen. *Schistosoma mansoni* existed in 8 EMR countries: Djibouti, Egypt, Libya, Oman, Saudi Arabia, Somalia, Sudan and Yemen.

During the past 20 years, much progress in combating the disease has been achieved based on WHO recommended strategies. Schistosomiasis has been eliminated in Iran, Lebanon, Morocco and Tunisia as no new cases were detected over the past few years. Furthermore, many other countries of the EMR, namely Egypt, Iraq, Jordan, Libya, Oman, Saudi Arabia and Syria, have now reached low schistosomiasis endemicity. The Regional Committee for the Eastern Mediterranean in its 54th Session adopted a resolution calling on countries in low transmission areas, where the implementation of the WHO recommended strategy has been successful, to “sustain successful control activities in order to eliminate schistosomiasis”.

The passage from low endemicity to zero is indeed a challenging task and will certainly require innovative strategies and more sensitive tools suitable for widespread use in low transmission areas. Therefore, it was necessary to held a meeting aiming to bring managers of schistosomiasis control programs (who succeeded to bring schistosomiasis down to low endemicity), together with relevant research experts to review the status of the schistosomiasis programmes in low endemic countries of the EMR; to define and adopt strategies for the elimination of schistosomiasis adapted to country situations; and to identify priority control oriented research needed and to develop Coordinated Regional and Country plans.

From 6-8 November 2007 more than 30 international experts and representatives from EMR countries where successful elimination/control of schistosomiasis has been achieved met in Muscat, Oman, in an informal consultation on “Strategies to Eliminate Schistosomiasis from the Eastern Mediterranean Region”.

Reports from all represented countries have clearly demonstrated that significant reductions in morbidity and mortality were achieved based on sustained chemotherapy. In *S. haematobium* endemic countries, as the disease became no longer a public health threat, sustained control efforts based on mass chemotherapy, health education and selective snail control lead to elimination of the disease. Such countries (Morocco, Jordan, Libya and Syria) presented data indicating that no new *S. haematobium* indigenous cases were detected over the past few years. Also, Egypt and Saudi Arabia managed to decrease *S. haematobium* prevalence to a relatively low level (1.2% and 0.6%, respectively).

*Schistosoma mansoni* endemic countries managed to reduce and then sustain endemicity at low level. The group noted that reduction in *S. mansoni* parasite reservoir in humans is slower than that observed for *S. haematobium*. Several factors may account for such observation, including that drug efficacy against the two parasites may be different, natural environmental changes may be unfavourable for *S. haematobium* transmission and the role of natural animal reservoir hosts (rodents and baboons) for *S. mansoni* in certain areas. Further studies are required to determine the significance of such animals in sustaining transmission regardless of human treatment.

Where elimination of schistosomiasis is aimed for, case detection may be a problem, as methods (clinical and parasitological) commonly used may lack necessary
sensitivity. The group discussed available alternative tools and advised that algorithms should change to incorporate more sensitive high throughput and inexpensive advanced technologies. Recommendations were agreed on incorporation of serological, antibody detection, methods to be used for testing endemic residents and, molecular methods for testing snail intermediate hosts. Furthermore, the group advised that antibody detection methods could preferably be useful in testing preschool and school age children for detecting endemic areas with very low transmission rates.

As the parasite reservoir decreases, more efforts to enforce current control activities in low-transmission areas in order to achieve elimination of schistosomiasis will be required. Programmes approaching elimination (zero cases) should consider focusing on transmission control measures including hygiene and sanitation improvements and sustainable biological snail control measures.

Programmes should initiate and maintain surveillance activities to detect possible resurgence/re-introduction of schistosomiasis infection (to sample within traditional transmission areas, non-traditional but “at risk” areas and, where appropriate potentially infected immigrants). Individual countries could possibly demonstrate elimination of schistosomiasis from their endemic areas by documenting absence of new locally contracted infections over an appropriate period of time. However, there was no consensus on how long the surveillance period would last as this would vary from country to another based on the risk of resurgence/re-introduction of infection of the disease.
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Message from the Regional Director

Dr Jihane Tawilah, WHO Representative, Oman, delivered the opening speech of Dr Hussein A. Gezairy, WHO Regional Director for the Eastern Mediterranean.

Ladies and Gentlemen, Dear Colleagues,

It gives me great pleasure to welcome you to this intercountry meeting on strategies to eliminate schistosomiasis in low endemic countries of the Eastern Mediterranean Region. I wish at the beginning to thank the Government of Oman for hosting the meeting, and for its strong political support, hard work and dedication to the schistosomiasis elimination programme.

This meeting is being held at an opportune time, just two weeks after the Regional Committee for the Eastern Mediterranean in its Fifty-fourth Session adopted a resolution calling on countries in low transmission areas, where the implementation of the WHO recommended strategy has been successful, to “sustain successful control activities in order to eliminate schistosomiasis”. This passage from low endemicity to zero is indeed a challenging task and will certainly require innovative strategies and more sensitive tools suitable for widespread use in low transmission areas.

I would like to thank our distinguished guests—research experts from China, Egypt, France, Palestine, Sudan and the USA—for their time and for sharing their expertise. The presence of our colleagues from WHO headquarters, demonstrates the high level of WHO’s commitment to support elimination of schistosomiasis from Eastern Mediterranean Region countries with low endemicity. Also gathered with us today are the programme managers who will share evidence-based information and data on the current situation of schistosomiasis in their countries.

I would like to draw your attention to the objectives of the meeting, which are: to review the current situation of the schistosomiasis programmes in low endemic countries of the Eastern Mediterranean Region; to define and adopt strategies for the elimination of schistosomiasis, adapted to country situations; to identify the priority control-oriented research needed; and to develop coordinated regional and country plans of action.

During the past 20 years, much progress in combating the disease has been achieved. Schistosomiasis has been eliminated in Islamic Republic of Iran, Lebanon, Morocco and Tunisia, providing evidence that not only is schistosomiasis control feasible but, in some situations, elimination of transmission can be contemplated. Also, thanks to commendable efforts, many countries of our region, namely Egypt, Iraq, Jordan, Libyan Arab Jamahiriya, Oman, Saudi Arabia and Syrian Arab Republic, have now reached low schistosomiasis endemicity. However, I hope that this success does not encourage countries to lower their guard. On the contrary, efforts should be further sustained and intensified to meet the remaining challenges and to bring this worthy and historic task to a successful conclusion.

Ladies and Gentlemen,

At present there is a need to understand the elements that have sustained schistosomiasis prevalence at such low levels and have prevented the countries concerned from reaching zero prevalence at a reasonable pace and cost. These factors may vary from one country to another. While undetected and untreated infections may be responsible for persistence of transmission in some endemic foci, certain wild animal species have been found to be naturally infected with the human strain of *Schistosoma mansoni*, suggesting their possible role as reservoir hosts. Furthermore, the proportion
of missed infections increases after chemotherapy, resulting in overestimation of cure rates.

The strategies selected to eliminate schistosomiasis will be based primarily on understanding whether such low endemic foci have resulted from: efforts to reduce morbidity and transmission; factors enhancing resurgence of transmission; in areas that have succeeded in interruption of transmission; or introduction of schistosomiasis in formerly non-endemic areas.

Partnership between research experts and programme managers is becoming crucial to assure implementation of proven valuable methods and approaches in a cost-effective manner. I am delighted to see that this meeting is offering such an opportunity.

The Regional Office will provide support for operational research to answer unresolved issues defined as a priority during group discussions. Scenarios to eliminate the disease may vary from one country to another, but we should learn from each other. We must remember that, together, we can make a difference. You are the leaders in the schistosomiasis field in the Region, and through cooperation and sharing responsibility, solidarity and commitment; we will be able to reach the goal to eliminate the disease in low endemic countries, God willing.

Thank you.
INTRODUCTION

Schistosomiasis (also known as bilharzia), a water borne parasitic disease, is endemic in 74 developing countries worldwide, infecting more than 200 million people in rural and peri-urban areas. Of these, 120 million have symptoms of the disease of whom 20 million have severe consequences. An estimated 650 million people worldwide live in endemic areas, and thus are at risk of acquiring the infection.

Schistosomiasis represents one of the major communicable diseases of public health and socio-economic importance in the Eastern Mediterranean Region (EMR). Direct mortality is relatively low, but the disease burden is high in terms of chronic pathology and disability. The Schistosoma species that exist in the EMR countries are the two human schistosomes Schistosoma mansoni and S. haematobium, and S. bovis, a bovine schistosome that may potentially infect humans and, more importantly, that may hybridize with S. haematobium (some S. bovis genes were found to be introgressed into S. haematobium genome). Schistosoma mansoni exists in 8 EMR countries, with Libya, Egypt and Saudi Arabia corresponding to the Northern limit for the species, with Oman, corresponding to the Eastern one and with Sudan, Yemen, Djibouti and Somalia. The snail intermediate hosts are in the North and in Yemen Biomphalaria alexandrina, in Egypt, B. alexandrina is found together with B. glabrata which was introduced several years ago, B. sudanica in Sudan and B. pfeifferi in all the other countries, including Oman, as it was found that B. arabica has now to be considered as B. pfeifferi according to recent molecular studies. Schistosoma haematobium exists in 14 EMR countries with, Morocco, Tunisia, Libya, Egypt, Jordan, Lebanon, Syria, Iraq and Iran corresponding to the Northern limit for the species and with Sudan, Djibouti, Somalia, Saudi Arabia and Yemen. The snail intermediate hosts are in the North Bulinus truncatus, in the West B. globosus, in the Eastern part B. wrighti which exists in Oman without the schistosome and in the South, B. beccarii and B. abyssinicus. Schistosoma bovis is known to exist in 7 EMR countries with Morocco, Tunisia, Iraq and Iran corresponding to the Eastern limit for the species. The snail intermediate hosts are in the North Bulinus truncatus, in Sudan B. truncatus is found together with B. globosus and B. forskalii, in Somalia B. abyssinicus. Thus, 15 EMR countries harbour schistosomiasis among the 22 and 7 are free of this disease. Egypt and Sudan (for the Nile Valley) and Somalia harbour the three species of Schistosoma. Seven countries harbour the two human schistosomes. The countries that harbour S. mansoni also harbour S. haematobium, except Oman that is free of S. haematobium. Finally, each country harbouring S. bovis also harbours S. haematobium.

During the past 20 years, schistosomiasis was eliminated in Islamic Republic of Iran, Lebanon and Tunisia. Mortality, morbidity and transmission of the disease were greatly reduced in Egypt, Iraq, Jordan, Morocco, Saudi Arabia and Syrian Arab Republic. Schistosomiasis and soil-transmitted helminthiasis infections remain a major public health problem in Sudan, Yemen and some areas of Somalia. 8 million people are infected by schistosomiasis in Sudan (5 million) and Yemen (3 million).

Praziquantel (PZQ), an effective drug, has been used successfully over the past 20 years to control schistosomiasis in several endemic countries including Brazil, Cambodia, China, Egypt, Morocco and Saudi Arabia. In many areas, schistosomiasis infects a large proportion of children under 14. It is believed that treatment at least three times during childhood is likely to prevent disease in adulthood.
Country reports:

Oman

Health authorities in Oman have been concerned with schistosomiasis in the Dhofar Governorate (population of approximately 240,000 people, of which >30% are expatriates, some of whom are from schistosomiasis endemic countries in Africa), South of Oman since early 1980s (Figure 1). This is because snail species (*Biomphalaria pfeifferi*) with a potential to transmit *Schistosoma mansoni* is widely spread in many parts of Dhofar Governorate. An intermediate host snail (*Bulinus wrighti*) for *S. haematobium* was also detected in one isolated effluent of a spring close to Salalah, the capital of Dhofar Governorate.

In 1982, the first snail survey was carried out in Dhofar Governorate and 5 water bodies around Salalah were found to harbor *B. pfeifferi* snails. Latter in the same year, out of 40 workers in Razat Farm surveyed by stool examination, 10 cases (25%) were detected with *S. mansoni* infection. Consequently, the Ministry of Health started a schistosomiasis control programme (SCP) in 1983. The main components of the control programme strategy were: 1) snail surveillance and control with chemical molluscicides, 2) environmental improvements, 3) health education, and 4) active case detection and treatment.

Of about 120 water bodies (very small basins and irrigation canals) surveyed (during 1983-1985) for presence of intermediate host snails, *B. pfeifferi* snails were found in 22 water bodies distributed mainly in the green mountainous areas, some are quite remote. All were treated with chemical molluscicides, and spraying of molluscicides continued thereafter depending on certain epidemiological factors including density of snails, human-water contact, detection of infected cases, and potential risk of transmission. Environmental improvement included providing proper facilities (potable water and public toilets in potential transmission sites) and to maintain the water bodies clean. Health education campaigns targeted schoolchildren and affected communities using different channels including mass media, however, in rural areas illiteracy remained a main barrier of public awareness. Active case detection was directed mainly to screening schoolchildren (6-17 years old) and screening of expatriates coming back from endemic countries (e.g. Egypt and Sudan) especially farm works.

During the 1990s schistosomiasis has been well under control as very low numbers of Omani infected cases (0-2 cases/year) were detected during stool surveys and non among screened expatriates. However, of 578 screened subjects, 13 (2.2%) infected cases were detected in 2000. Consequently, health authorities decided to carry out a wider investigation to clarify the situation of *S. mansoni* transmission in Dhofar. School surveys, using parasitological techniques, in rural areas of Salalah revealed an overall prevalence of *S. mansoni* infection of 4.5% (36/800, range 0.7%-12.9%). School serological surveys, in the same area, showed a wide range of *S. mansoni* infection rates 3%-47%. Based on these data and findings from snail surveys, five potential *S. mansoni* transmission sites (Sahalnot, Razat farm, Darbat, Tibraq and Siginniti) were identified.
By 2003, a 5-years programme for elimination of schistosomiasis in Dhofar was initiated. The programme intends to interrupt transmission taking into account the possibility of existence of animal reservoir hosts. Rodents (*Rattus rattus*) in Dhofar were found to be naturally infected with *S. mansoni*. However, the significance of such infection needs to be further considered and evaluated. The elimination strategy included active case finding based on improved diagnostic methods (parasitological and serological) and effective treatment, with mass chemotherapy in populations with >25% infection in schoolchildren; surveillance of 7th grade schoolchildren (previously shown to be the highest infected age group); and monitoring water bodies for intermediate hosts snails implement measures aiming to interrupt transmission of schistosomiasis in Dhofar.

**Future perspectives and plans:**

As Oman became a low schistosomiasis endemic area, use of more advanced diagnostic methods is required for effective case detection and monitoring of transmission. Please describe in details (where, how many samples and for how long) how the programme would proceed with performing serological, antibody detection, methods for testing endemic residents and, molecular methods for testing snail intermediate hosts. Would the programme consider further investigation on the role of rodents as possible natural reservoir hosts? If so, please provide detailed plan.

**Egypt**

Both species of human schistosomiasis, *Schistosoma haematobium* and *S. mansoni*, are endemic in Egypt since ancient times. The former species causes urinary tract lesions and bladder cancer, and the latter causes gastrointestinal and hepatic manifestations. The disease has always been considered one of the major public health problems in the country with wide distribution all over the Nile valley. The disease epidemiological picture has changed over the years.

The first country-wide survey was carried out by Scott during the period 1932-1934. He described the distribution of the disease, while *S. mansoni* was restricted to the northern and central parts of the Nile Delta; *S. haematobium* was highly prevalent.
throughout the Nile valley and Nile Delta, where many subjects were infected with both species. The prevalence of both species was about 60% in rural populations of the northern and eastern parts of the delta. In the south-central part of the delta, the prevalence of *S. haematobium* remained at 60%, but that of *S. mansoni* was only 6%. *Schistosoma mansoni* was not prevalent south of Cairo in Upper Egypt. Note that Scott data were not based on randomly selected subjects; instead the studied populations were selected as representative for their endemic districts. Furthermore, parasitological methods used for examination of urine and stool samples were rather insensitive.

In the 1960s, following the construction of the Aswan High Dam, changes in distribution of infections with both species gradually took place. While the prevalence of human *S. haematobium* infections decreased throughout the Nile valley, there was a significant increase in the prevalence of *S. mansoni* in the Nile Delta.

The Ministry of Health and Population (MOHP) has always considered control of schistosomiasis a prime public health priority. In 1976, MOHP started a national schistosomiasis control programme (NSCP), based on case detection and treatment. The objectives of the NSCP were: (1) Control of morbidity by reduction of the prevalence and intensity of infection, thereby limiting complications (2) Protection of young age groups and other at risk populations (3) Protection of settlers in newly reclaimed lands, and (4) Prevention of the spread of *S. mansoni* to Upper Egypt.

By 1989, the distribution of PZQ doses, free of charge, to all diagnosed schistosomiasis cases was implemented through different health facilities including the network of rural health units. Chemotherapy was frequently supplemented with focal snail control with chemical molluscicides (niclosamide at 1-2 ppm). By 1997, the MOHP started to distribute PZQ to endemic populations without prior diagnosis. These included schoolchildren (4.3 million) in 11 governorates and the entire population (2.9 million) living in 535 villages with estimated prevalence of schistosomiasis (intestinal and/or urinary) higher than 20%. The prevalence rate level at which mass chemotherapy was offered to a village has decreased over time, being 10% in 1999, 5% in 2000 and 3.5% in 2002. Consequently, the overall prevalence of both *S. haematobium* and *S. mansoni* declined steadily, year by year (Figure 2).

![Figure 2: Overall prevalence of schistosomiasis in Egypt during the period 1935-2006](Image)

(Source: National Schistosomiasis programme in Egypt)
Currently (by the end of 2006), *S. haematobium* has virtually disappeared from the Nile Delta, however, still present in Upper Egypt with a prevalence rate of 1.2%. The overall prevalence rate of *S. mansoni* in the Nile Delta declined to 1.5% (Figure 1). All endemic villages (744 villages) have prevalence rates 1%-3%, however 68 villages (mainly in Behera and Sohag governorates) remained with slightly higher prevalence (range 3%-5%). No morbidity associated to schistosomiasis has been seen in recent years in Egypt.

In conclusion, NSCP has succeeded to significantly decrease the prevalence and intensity of schistosomiasis (intestinal and/or urinary) to a low level such that the disease is no longer a major public health problem. It is hoped that the programme will enforce/sustain current control activities in low-transmission areas in order to achieve elimination of schistosomiasis. In the same prospect, initiate and maintain surveillance activities to detect possible resurgence/re-introduction of schistosomiasis in areas now free of infection.

**Future perspectives and plans:**

In 2007, the MOHP has decided to move the control programme forward to achieve elimination of schistosomiasis from Egypt. To accomplish the goal of elimination, the programme plans to implement several rounds effective mass chemotherapy (1-2 rounds/year) in “hot spot” areas. This will be integrated with other interventions; snail control using chemical molluscicides in active transmission sites, improve village environmental conditions, provide water supply to endemic villages, and enforce health education and behavioural changes. To implement such ambition programme, input from other organizations would be required in an integrated multi-sectoral approach. These would include Ministry of Local Development, Ministry of Water Resources, Ministry of Education, Ministry of Agriculture, Ministry of Housing and New Communities, Ministry of Media and Information, Ministry of Environment and, Societies and non-governmental Organizations.

**Saudi Arabia**

Epidemiological surveys conducted during the 1970s indicated that both *S. mansoni* and *S. haematobium* were endemic in 12 regions in the Kingdom of Saudi Arabia (KSA), with a patchy distribution and varying infection rates reaching up to 40% in some foci, causing an important public-health problem. Three species of snails namely, *Bulinus beccarii*, *B. truncatus* and *B. wrighti* transmit *S. haematobium* and *S. mansoni* is transmitted by *Biomphalaria pfeifferi*.

In 1977 the national Ministry of Health (MOH) launched a programme to control the disease utilizing the established schistosomiasis-control centers in all endemic regions. The main components of the control strategy were: case detection and treatment of infected people (using available drugs: antimonials, niridazole or metrifonate), control of fresh water snails (chemical agents such as cupper sulphate and/or mechanical measures) and relevant health education. In early years, the programme met with very little success. However, since 1982 onwards the replacement of the old anti-schistosomal drugs with PZQ, together with the identification and regular treatment of snail-infested water-bodies, led to significant reductions in the prevalence of human infection with *S. haematobium* in most areas. By 1989, infection with *S. mansoni* has dropped in foci of the infection in the Central Region (Riyadh and Hail) and in all foci within the western provinces. During 2002-2004 approximately 18,000 subjects were investigated, the prevalence of *S. haematobium* infection fell from 1.7% in 2002 to 0.7%
in 2003 and to 0.6% in 2004. Figure 3 shows the number of *S. haematobium* reported cases in KSA during the period 1981-2006.

Socio-economic development of KSA, which has resulted in a general rise in living standards, improved sanitation and water supplies, construction of drilled wells in rural areas and a significant increase in medical care, encouraged the MOH to work for total elimination of the disease from the Kingdom. By 2005, a national programme for elimination of schistosomiasis was initiated in all emirates (districts) in the known 12 foci. They were classified into 3 groups according to endemicity of schistosomiasis. Group (A) included 4 regions, believed to be schistosomiasis free (Riyadh, Hail, Tabuk, and Al Jouf), Group (B); low endemicity regions (Al Madina Al Monawara, Najran, Al Assema Al Moqaddassa, Jeddah (including Alleith) and Al Taif); and Group (C) high endemicity regions (Jazan, Al Baha, Assier and Bisha). In 2007 the following regions were declared as disease–free areas (zero incidence rates), these include: Al Medina Al Monawara, Riyadh, Hail, Tabuk, Al Jouf and Najran. The strategy for disease elimination in the remaining endemic regions include: 1) active case detection and treatment by examination of 80-100% of the endemic population once a year and 80-100% of schoolchildren in the same areas, twice a year; 2) safe potable water supply and good sanitation are made available to endemic communities; 3) snail control using chemical molluscicides and mechanical methods; 4) health education is intensified through different channels.

![Figure 3: Number of reported *S. haematobium* cases in KSA during the period 1981-2006](image)

Hamadryas baboons occur in large numbers in the west of Saudi Arabia. They share the same water sources with man in schistosome endemic areas. Natural infection with *S. mansoni* has been reported in these baboons. Thus, it is possible that they act as maintenance/reservoir host of *S. mansoni* and, therefore, could hamper schistosomiasis control measures if those were based only on mass chemotherapy.

**Future perspectives and plans:**

Significant progress has been achieved over the past 30 years in the control of schistosomiasis in KSA. The future plans include the following activities: i) enhancement of the Electronic Information System (MoH, Riyadh) on the epidemiology, diagnosis, and control strategies; ii) to sustain efforts to prevent resurgence of schistosomiasis. These can be achieved by implementing a surveillance system based on using serological techniques which are easy to perform, allow screening of large population, possess high
sensitivity and cost-effective. Health education will be continued as a supplement to control/elimination activities.

**Libya: (Libyan Arab Jamahirya)**

Historically, schistosomiasis due to infection with *S. haematobium* and *S. mansoni* has been found in certain localities in Libya. In 1925, *S. haematobium* was recorded in the region of Ghat (near the Algerian frontier). Since 1957, *S. mansoni* is endemic in the oasis of Taourga about 50 km south of Misurata. *Bulinus truncatus* and *Biomphalaria alexandrina* are the snail intermediate hosts for parasites causing the urinary and intestinal forms, respectively. Currently, while *S. mansoni* remained localized only in Taourga, *S. haematobium* has virtually disappeared from all previous endemic areas except in Alfogaha where it is suspected as infected snails were detected, but so far no human infection was detected.

The population of Taourga is approximately 21,000 people. The health facilities consist of one rural hospital and two health centers to provide health care to the community. In 1998, the prevalence of *S. mansoni* in the community accounted for 21.9% and in school age children was 28.9%. In 1999, the latter increased to 39.8% with one school as high as 55%. Recently, control activities were enforced, these included screening of the total population and providing free PZQ treatment to infected subjects, increasing awareness of the endemic population and snail control using mechanical and biological measures. Currently, after screening about 71% of the Taourga population, 3% were infected with *S. mansoni* (mostly live around the Taourga lake), but no *S. haematobium* infection was detected.

**Future perspectives and plans:**
It is planned to continue mass treatment of people residing around the Taourga Lake. This process will be repeated every year for elimination of the infection/disease. Health education of endemic populations especially schoolchildren will be continued. Suitable biological methods for snail control will be implemented instead use of chemical molluscicides. With regard to Alfogaha, training sessions for doctors and laboratory technician working in its health center will be conducted. Field surveys to examine humans as well as snails for *S. haematobium* infection will be performed.

**Jordan**

Prior to 1980 schistosome infections had been reported in immigrant workers. Following the report of the first indigenous case of urinary schistosomiasis in 1975 in the Jordan valley, *Bulinus truncatus* was found in many water bodies, mainly irrigation pools, in 8 out of the 12 provinces of the country. *B. glabrata* has never been found in the country. Screening of urine samples was initiated in the early 1980s and since then 10,000-60,000 samples have been screened annually. In the early 1980s infection rates of up to 8% were seen in migrant workers from Egypt working in agriculture near water-bodies harboring host-snails although this dropped to <5% in the 1990s. Such infection rates were actually higher than in Egypt due to implementation of mass chemotherapy there. Annual numbers of infections declined from the mid 1990s and in 2006 112 *S. haematobium* and 11 *S. mansoni* cases of imported schistosomiasis were reported.

Sporadic outbreaks of transmission within the indigenous population have been reported since the early 1980s. During 1984-1989, 40 local cases were detected near a hot spring near Al-Hassa stream South Jordan; during 1994-1996, 10 local cases were detected in Jordan Valley due to swimming in cemented pools; and during 1997-2003
100 local cases registered in Ghor Al-Safi South Jordan, all in boys of school age who had been swimming in irrigation pools (Figure 4). The last local cases were registered in 2003 (7 cases in Al-Safi) and since 2004 no local cases have been registered.

The indigenous population at risk of Urinary Schistosomiasis is currently estimated to be around 360,000, nearly 6% of total population of Jordan. Although *B. truncatus* has disappeared from the north of the country in part due to chemical pollution but also perhaps climate change, many sites in the South remain infected, notably: Al-Hassa stream and the >700 irrigation pools in Al-Safi lowlands where banana plantations have expanded.

![Figure 4: Number of reported *S. haematobium* cases in Jordan during the period 1983-2006](image)

Control strategies have been integrated with the malaria control programme and have involved active case detection among foreign workers coming from schistosomiasis endemic countries (mainly Egypt but also Sudan) and working in high-risk areas; passive case detection through clinics and hospitals; screening of workers during the examination needed for residence permit; mass screening of school children at risk during outbreaks; treatment of positive cases and follow up after treatment; regular surveillance of water bodies for the presence of *B. truncatus* snails. Chemical control of positive sites with niclosamide (1 ppm) is used where possible but is difficult in some settings owing to inaccessibility, fish growing in irrigation pools and cost.

**Future perspectives and plans:**

Surveillance activities are planned in the 3 foci where last sporadic outbreaks of transmission occurred. For such investigation, surveys using sensitive and specific antibody detection methods will be used. Age specific antibody prevalence rates will be assessed as indicator for determine the status of schistosomiasis endemicity. Antibody positive subject will then be examined by parasitological methods. Foreign workers will also be screened for schistosomiasis by same sero-diagnostic assays. Water bodies known to contain *B truncates* snails will be monitored. The plan is to carry out multiple surveys to screen water bodies for presence of infected snails. Infection in snails will be determined by newly developed molecular assays.

**Morocco**

Cases of *S. haematobium* were first detected in 1914. However, there is strong evidence that schistosomiasis was endemic in the southern part of Morocco long before then principally along the ancient trade routes coming from the Middle East and
Subsaharan Africa. Over the last three decades, the development of irrigation led to the spread of the disease, carried by *B truncatus*, to the north and centre of the country resulting in ecologically diverse endemic foci: oases and arid areas; intermittent streams in mountainous areas; modern irrigation schemes; coastal plains, swamps and rivers.

A Control Programme was initiated in 1976 and in 1981 a National Programme of Schistosomiasis Control was launched by the Ministry of Health in all endemic provinces (20) with the objectives of reducing morbidity and preventing extension of transmission of disease. The programme, which received technical and financial support from WHO, was based on selective (in known localities) and mass (in schools) case detection and treatment; surveillance and control of snails using chemicals, by environmental modification and by maintenance of irrigation systems; health education; and intersectorial collaboration involving the Ministries of Agriculture and of the Interior. Before 1982 the drug of choice was niridazole, which was replaced by metrifonate from 1982 to 1986 and by praziquantel in 1988. 6,582 cases were reported in 1982 and the number of cases peaked in 1983 with 10,635 cases.

As a result of the Control Programme the prevalence was progressively reduced, 1,137 cases being reported in 1993 when a Schistosomiasis Elimination Programme (SEP) was initiated and launched in 1994. The aim of the SEP was (i) to eliminate indigenous schistosomiasis transmission by the end of 2004 and (ii) to prevent the revival of schistosomiasis transmission in known endemic areas during the consolidation phase 2005-2010. To achieve this, the ongoing activities were intensified and urgent interventions were initiated in cases of reactivation of infection i.e. mass case detection (schools and localities), mass chemotherapy in the endemic localities and surveillance and control of intermediate host. In addition there was monitoring and regular evaluation of the efficacy of the interventions. Parasitological monitoring was extensive with 149,718 samples being tested in 2000, 130,826 in 2004 and 90,470 in 2006. Numbers of cases continued to drop progressively between 1994 (1108) and 2002 (42) but an outbreak in Tata led to a transient increase in 2003 (Figure 5). By 2004 the last focus of transmission in Tata province yielded only 9 autochthonous cases. There was no recorded transmission in 2005 and 2006, the cases notified (9 and 2 respectively) being acquired before 2005. However, during these years 4 and 2 imported cases respectively were detected.

![Figure 5](image.png)

**Figure 5:** Number of reported *S. haematobium* cases in Morocco during the period 1994-2006

**Future perspectives and plans:**

Following a national meeting in December 2004 the Elimination process was deemed to have entered a Consolidation phase 2005-2010. This has been characterised
by (1) maintenance of the surveillance activities with a focus on detection in previous endemic localities and schools (children under 10 years of age enrolled or non-enrolled) to detect renewed transmission (2) epidemiological surveys around any such cases and mass treatment (3) Continued surveillance of water bodies (323 water bodies were surveyed in 2006) and control of snail hosts. This surveillance process will be continued until 2010. The plan for activities during the period 2008-2010 will include: Monitoring of school age children (5-15 years): (A) in the 2 provinces with no transmission for more than 5 years, FAST-ELISA will be used on samples from children in schools with epidemiological history of transmission (B) in other areas (transmission last seen in less than 5 years) parasitological screening will also be continued.

Syria:

Urinary schistosomiasis was introduced into Syria during the Second World War by African soldiers and became established in localised areas in the north-eastern provinces bordering Turkey. Transmission was eliminated from these original foci but with irrigation the infection spread to villages along the Belikh and Euphrates rivers along with the intermediate host snail, *Bulinus truncatus*.

In 1987 the number of positive cases reported was 2,444 but, following the implementation of control measures, cases decreased to 344 cases in 1993, 5 in 2002 and only one in 2004 (Figure 6). These latter cases were restricted to Raqqa province. This reduction in prevalence can be credited to early detection and treatment of cases and contacts, increased safe water supply, land reclamation associated with filling of marshes and monitoring and mollusciciding of snail intermediate hosts (only 417 *B.truncatus* were recorded along 370km of the Belikh and Euphrates in 2006). No cases were reported 2005-2007 but an estimated 150,000 people are considered at risk of infection in the traditional foci.

**Figure 6:** Number of reported *S. haematobium* cases in Syria during the period 1993-2007

Although the reduced prevalence is undeniable no data have been officially published. The number of infected subjects has decreased; however, the prevalence of *S. haematobium* infection at the national or in any affected province is not reported.

Current control activities are: Health education; increasing supply of drinking water; screening for cases and contacts followed by treatment; improvement of healthcare facilities and integration of schistosome monitoring with these; management of the
environment; control of the intermediate hosts by monitoring and mollusciciding each June and September.

**Future perspectives and plans:**

In 2006, 3,144 urine samples from school children and adult population in transmission areas were screened using parasitological methods. For future monitoring it is proposed to continue screening of urines and to implement testing of 3000-4000 schoolchildren aged 6-14 years by serological assays in traditional foci. In addition to the traditional “hot spots”, monitoring would be extended to other locations notably along the Euphrates.

**China**

In the mid 1950s, when China’s population was approximately 600 million, an estimated 11.8 million people were infected with *Schistosoma japonicum*. Transmission occurred in streams in mountainous and hilly areas, in Lake and marshland areas and in the plains. A national control programme was launched in the 1950s initially based on nationwide surveys and treatment. In the 1960s and 1970s the emphasis shifted to intermediate host snail control by means of environmental management and also chemical mollusciciding. This led to elimination of the disease in four of the 12 formerly endemic provinces and the number of human infections reduced from 11.6 million to 1.64 million but morbidity remained a serious problem with more than 20,000 cases of advanced schistosomiasis, and environmental pollution limited molluscicide application. Following its introduction in 1980s praziquantel-based morbidity control became the mainstay of control effort and was supported by the 10-year World Bank Loan Project (1992-2001) complemented with health education and continued snail control. Between 1992 and 1998 there was around 50% reduction in the prevalence of infection in both humans and cattle and a reduction of 75% in the density of infected snails in high transmission areas and by 2000 the number of infected people had been reduced to an estimated 694,788 (Figure 7), the snail-infested area has been reduced by over 75%, and the disease had been eliminated in 5 of the 12 previously endemic provinces.

![Figure 7: Number of reported *S. japonicum* cases in endemic provinces in China during the period 1950-2004](image_url)

However, success was greatest in the plain regions whereas infection rates in the 7 provinces comprising the lake and marshland areas were not reduced between 1980-2000. Furthermore, comparison between the number of cases in 2000 and 2003 suggested that, following the end of the World Bank loan, schistosomiasis had re-emerged since 843,007 people were found to be infected with *S. japonicum* in 2003 (Figure 8).
The factors responsible for the re-emergence of infection in some areas have been identified as (1) Ecological transformations (the floods in 1998, implementation of new anti-flood policy, global warming); (2) Social and economic changes (large-scale population movements, poverty and inequity of health services; (3) Insufficient funds to national control programme (End of World Bank Loan Project, Lack of capacity). So despite the huge successes in China since the 1950s the failure to interrupt transmission in some areas and the recent reversals in others have shown that there can be no let up in the intensity of control measures and also that the methods which may have been successful in some areas may need to be modified or supplemented in order to make progress towards elimination.

Acceptance of this led to a redoubling of the determination of the Government of China to control the disease and in 2004 schistosomiasis was put as a top priority amongst communicable diseases, grouped together with HIV/AIDS, tuberculosis and hepatitis B. The overall aim for the national schistosomiasis control programme was put forward to reach the infection control by 2008 and transmission control in 2015 nationwide.

By acknowledging the deficiencies and gaps in the traditional control efforts based on chemotherapy and snail control it was clear that there was a pressing need to refine control strategies, particularly in the lake and marshland region, where more than 80% of human infections are concentrated. A novel, integrated control strategy has been designed with the emphasis on reducing egg contamination to the environment with human and animal faeces e.g. replacing cattle with machineries, fencing bovines and forbidding exposure to snail-infested grassland, improving sanitation by building home lavatories and public latrines with three-cell septic tanks, constructing household marsh gas pools, tap-water supply to each households, and providing fecal containers to all boats. This complements conventional counter-measures, such as health education, focal mollusciciding, praziquantel treatment.

Results showed that after two transmission seasons, human infection in two villages in Jiangxi province (with initial rate of 11.3 and 4.0 percent) decreased by 85% percentage of snails infected decreased by 57.1 percent and the infectivity of lake water
to mouse infection decreased by 97% percent. This new integrated control strategy also showed a significant impact on soil-transmitted helminthiasis as well.

The lessons from China, albeit faced with the more challenging zoonotic infection, are that relentless effort and vigilance is necessary to make progress towards elimination and that sometimes it is necessary to reappraise the methods being used and to implement new ones if necessary and economically feasible.

**Strategies for schistosomiasis control in low transmission areas**

The main components of strategies to control schistosomiasis at a country level include the following efforts: 1) Morbidity control, this is achieved by mass chemotherapy of safe drugs (PZQ) to all populations at high risk; 2) Infection control, by selective treatment of infected individuals as detected, resulted in significant reductions in morbidity and mortality; 3) Transmission control, more costly and depends on available resources to provide potable water, safe sanitation, environmental modification as appropriate, and snail control (chemical and/or mechanical). These strategies are not mutually exclusive as all operational components will result in reduced infection levels and less morbidity (Figure 9). It is particularly important to supplement control strategies with health education to create population awareness and facilitate community participation. Selection of suitable national programme components would vary according to the country situation and available resources.

Where elimination is aimed for, it is important to complete the schistosomiasis epidemiological picture as possible. This would include mapping of the endemic communities, determine whether infection is clustered in certain foci and establish the potential of transmission. Use of the geographical information system would be an advantage to facilitate longitudinal monitoring of endemic settings. For a sound and sustainable elimination programme, it is necessary to have well-developed public health infrastructure in terms of adequate facilities for diagnosis and treatment, reliable algorithms for diagnosis, safe water and sanitation services, as well as establishment of a robust surveillance system. Before launching the elimination programme, it is essential to ensure political will at high level and guarantee long term commitment of resources. This can be achieved by allocation/reallocation of national resources, development of intersectoral collaboration and integration with other relevant organization/institution, advocacy of short health messages for community mobilization and engagement of endemic populations to ascertain high drug coverage rates.

Diagnoses of schistosomiasis in low transmission areas would require more sensitive diagnostic tools than needed in areas with high prevalence rates. For instance, a parasitological method such as Kato-Katz is useful for detection of heavy infections, but lack sensitivity in low transmission areas. Therefore, other methods e.g. the modified formol-ether concentration technique is more useful, its sensitivity can be increased by use of a larger stool volume and/or repeated sampling. Sensitivity of urine examination can also be compensated in the same way for proper use in low transmission areas. However, given the large number of examined samples before and/or after mass chemotherapy for evaluation of the elimination programme and for the surveillance phase, such parasitological methods are labour intensive and of low reliability, such that quality control becomes difficult. Serological assays (antibody or antigen detection) may play a major role in such circumstances. Certain antibody detection assays (adult worm antigens; MAMA, JAMA, HAMA and Sm31/32) have both high sensitivity and specificity (>95%) but cannot distinguish past and current infection. However using proper diagnostic algorithms, these assays may pin-point to hot spot of transmission site (see
next section). Indeed, there is a need for evaluation of a variety of the currently available antigen and antibody tests under field conditions in low endemic areas. Furthermore, countries in the Eastern Mediterranean Region where transmission has been interrupted and there are no new detected cases provide a unique opportunity for evaluation of such tools for post-transmission surveillance.

![Diagram showing the possible sequential intervention steps on the road towards elimination](image)

**Figure 9**: The possible sequential intervention steps on the road towards elimination (from morbidity control to transmission control) in areas reached low endemic level.

Currently, schistosomiasis is not globally targeted for elimination. Therefore, WHO has not established standard criteria for its elimination. As the elimination scenarios may vary according to the disease-country specific conditions (disease clustering in certain area e.g. Libya; existence of animal reservoir hosts?), individual countries are encouraged to develop their own elimination criteria/strategies. A country programme should have clear elimination criteria. A first goal should be morbidity control by identification of at risk populations and implementation of several rounds of safe mass chemotherapy. Once the parasite reservoir has significantly been decreased, the programme should change focus to transmission control. Operational priorities would include: health education to improve hygienic behaviour (reduce excreta from reaching the environment), supply of potable water and safe sanitation, environmental management (require intersectoral collaboration) and focal snail control where required.

Interruption of transmission can possibly be demonstrated by documenting that no new infections were contracted locally over an adequate period of time. The surveillance period, during which no cases should be detected with certainty to declare that transmission has been interrupted is not well defined and, would depend very much on the risk of re-emergence or re-introduction in a particular context. The degree of confidence that schistosomiasis has been eliminated depends very much on the performance of the surveillance system, in terms of sensitivity/specificity of the diagnostic methods used and the reliability of the reporting system.
Serologic assays to detect low level infections, endemic hotspots, and transmission interruption for schistosomiasis

To date, conventional diagnosis of schistosomiasis is dependent on parasitological methods for the detection of schistosome eggs in either stool or urine. However, because of low and sporadic egg production, the risk of undiagnosed individuals is tremendous. Undiagnosed individuals remain infected and transmission of the disease continues. Furthermore, the outcome of successful large-scale chemotherapy programmes, aiming to reduce the parasite reservoir, has been areas with low prevalence and persisting or new infections have low intensity. However, for the purpose of disease elimination, there is a need to continue diagnosis in such low prevalence areas to assess the magnitude of the remaining parasite reservoir, to determine whether transmission is still ongoing or, in some regions, to monitor infection status in immigrants. Use of parasitological methods has some drawbacks; 1) they have a relatively low sensitivity and so will miss a significant proportion of low intensity infections 2) they are labor intensive, considering the need to screen large numbers of individuals 3) less compliance of low endemic communities who have stopped perceiving morbidity. Serological methods (antibody or antigen detection assays) may play a major role to supplement or replace parasitological methods for diagnosis of schistosomiasis in low prevalence regions.

In the late 1980s and early 1990s, many diagnostic techniques have been developed, including detection of parasite circulating antigens, and detection of circulating antibodies to semi-purified or fractionated antigens in different host body fluids. Detection of specific antibodies to *S. mansoni* and *S. haematobium* adult worm microsomal antigens (MAMA and HAMA, respectively) was found to be 100% specific for both species when used in the Falcon assay screening test–enzyme-linked immunosorbent assay (FAST-ELISA) and in the enzyme-linked immunoelectrotransfer blot (EITB) assay for diagnosis of schistosomiasis. However, these findings did not receive much attention as, in general, results of antibody assays do not correlate well with worm burden, as measured by the egg output, nor do they discriminate between previous exposure and current infection. The use of reagents to detect circulating antibodies in field studies has been limited and such assays were usually conducted in highly endemic foci. However, few field studies have applied antibody detection assays in surveys of areas with low endemicity for *S. haematobium* and *S. mansoni*.

During 1998, in a systematic, island-wide, serologic survey for schistosomiasis in Puerto Rico, a total of 2,955 serum samples from the 76 municipalities comprising the island were tested for the detection of antibodies to the MAMA antigens by the FAST-ELISA and those positive were confirmed by the EITB assay. Seventeen municipalities comprised 48% of all seropositive samples, with 10% of the positives from individuals with ≤ 25 years of age residing in the “hot spot” areas. To determine the extent of infection in the younger individuals as an indicator of recent transmission, a sample of 507 subjects aged ≤ 25 (collected for a dengue fever survey) from same “hot spots” were used. No children 1-5 years old were found EITB positive and < 10% of children below 10 years of age were positive by FAST-ELISA, of which < 1% were confirmed by EITB. It was concluded that Puerto Rico has become a region of extreme low endemicity with little or no current transmission.

Preliminary data from a WHO/TDR multi-center trial of diagnostic tests for the detection of low transmission and light infections of *S. mansoni* and *S. haematobium* indicated that the sensitivity and specificity of MAMA-EITB assay were 94% and 100%, respectively. The test was performed at the Centers for Disease Control & Prevention, USA using 165 true positive infection sera from patients, excreting less than 100 eggs.
per gram feces in 3 consecutive samples, residing in Kenya, Egypt, Brazil, and Venezuela; and 92 true negative samples (sera from healthy U.S. residents who had never traveled abroad and heterologous infection, mostly other parasitic diseases/infections, sera from donors who reside in countries where schistosomiasis is not endemic).

By 2001, Morocco has reached very low incidence rate (<1%) of *S. haematobium* infection and detecting cases by urine examination became laborious and inefficient. In collaboration between the Egyptian Diagnostics Reference Center, Cairo University, Egypt and the Ministry of Health, Morocco, about 1500 blood samples were collected from 3 endemic areas suspected to have low incidence, (Chtouka, Marakech, Tata). Sera and whole blood samples were tested for the detection of antibodies to the HAMA antigens by the FAST-ELISA and those positive were confirmed by the EITB assay. The overall antibody prevalence (FAST-ELISA) in the three areas ranged 19-22%. Of especial interest was the finding that prevalence rates in 1-14 years old children were 0% in Chtouka and Marakech and 10% in Tata (Figure 10). Thus, the antibody detection tests were useful for detecting endemic areas with very low transmission rates. The transmission in Chtouka and Marakech is well under control and for the programme cost-effectiveness, intensive control measures should be focused on areas with antibody positive tests in young age groups.

![Figure 10: Age-specific anti-HAMA antibody prevalence rates of schistosomiasis haematobia in 3 low endemic areas in Morocco.](image)

**Molecular Tools for Monitoring Schistosoma-Infested water**

Various approaches for targeting chemotherapy to human populations would reduce the burden of advanced morbidity due to schistosomiasis, but were not sufficient to suppress transmission, with the resulting persistence of the risk of infection. Large-scale treatment campaigns can significantly decrease infection prevalence rates and reduce egg output; however, a single untreated individual can contaminate a water site and convert it to a high risk transmission zone for several months. Therefore, implementation of such control approaches require improved means for evaluating snail-to-human transmission variables.

Until recently, two techniques have been used for monitoring the impact of control programmes on the transmission potentials. 1) Assessment of the proportion of
snails that are infected and shed cercariae. It is well known that the rate of cercaria-shedding snails can be quite low, even in areas of high transmission. Therefore, examination of large numbers of snails are required to detect statistically significant changes in transmission potential over time, especially following implementation of control measures. 2) Cercariometry for monitoring schistosome-infested water by measuring cercariae numbers in the water at human contact sites. Cercariometry has not been applied routinely and still presents problems in practice and in data analysis.

The question of whether pre-patent infection can serve as an indicator of human-to-snail transmission was recently raised. Such approach could be more suitable for monitoring transmission in low endemic areas as the mortality of infected snails can be higher after cercarial shedding, pre-patent infection can last for several weeks with only a proportion of infections reaching the stage of cercarial shedding and so the pre-patent snail infection rates will always be substantially exceeding the number of shedding snails. Molecular assessment of the pre-patent snail infection rates will provide a sensitive and specific means to identify residual transmission risk. Indeed, molecular methods (based on the polymerase chain reaction, PCR) have been developed and used in limited field studies for detection of infected snails and for identification of potential transmission sites by monitoring cercariae infested-water. In an extensive examination of field snails the rate of snails with prepatent infection, as determined by PCR was found to reach about 30% to 50% of the host snail population even in an area where active control is taking place.

For *S. mansoni*, PCR amplification of a tandem repeated DNA sequences (Sm1-7, 121 bp, represents 12% of the *S. mansoni* genome) enables the detection of 1 fg DNA or a single cercaria, and have the potential to specifically detect parasite DNA in snails and monitoring of cercariae in water bodies. As yet, the assay has not received much attention or field evaluated.

A similar DNA repeat (*Dra*I repeat) of *S. haematobium* has been shown to enable detection of snail infection throughout pre-patency. The *Dra*I is a tandemly repeated sequence of 121 bp, comprising about 15% of the *S. haematobium* genome, its amplification by PCR, enabled identification of 1 fg DNA or a single cercaria (Figure 11). However, the *Dra*I was also detected in the genomes of closely related animal Schistosomes, including *S. bovis*, *S. intercalatum*, and *S. matheei*. Thus, the *Dra*I-PCR system can be applied in endemic areas where no related animal schistosomes are present. The *Dra*I-PCR assay was used in a large-scale monitoring of field snails and provided year-round data on pre-patent *S. haematobium* infections among snails recovered from transmission sites in the Msambweni in Kenya.

![Figure 6: Detection sensitivity by polymerase chain reaction employing DraI primers.](image)

Lanes 1–4, amplification products of 10 pg, 1 pg, 100 fg, and 10 fg DNA, respectively; M-size marker.

Recently, more efforts were directed towards the development of *S. haematobium* species-specific molecular assay. These resulted in the identification of a new *S. haematobium* repeated sequence, clone *Sh110* and the development of a PCR
assay, the Sh110-Sms1-PCR. The assay is based on the amplification of 525 bp DNA sequence employing two primers the Sh110 and Sms1 (S. mansoni splice leader sequence). While the new assay did not amplify DNA from S. bovis and S. mattheei, DNA from S. intercalatum and S. curassoni was amplified but could be differentiated from S. haematobium by the different banding pattern of their amplification products. The assay needs further laboratory and field validation using snails collected from sites where sympatric transmission of S. haematobium and other related species occur.

PCR-based assays are much less labor-intensive, tedious, and often more practical than the traditional method of snail dissection for large scale screening in endemic areas. PCR-based methods have the additional advantage that they can be used to detect single parasite in a pool of field collected snails. This can make their field application more cost-effective than dissection, particularly in areas where schistosomiasis prevalence becomes very low after effective intervention. By using them to screen pools of field collected snails and water from potential transmission sites, such methods can provide useful information on active transmission in a particular setting, enabling remaining “hot spot” sites to be identified and transmission in areas where infection is rare (as might be expected after an effective intervention) to be monitored.

In order to perform practical snails’ PCR; the following points should be taken in consideration: 1- Preservation of snails in 70% allows detection of schistosomal DNA in snails for 2 years. 2- Extracting DNA from snails was best achieved by the use of CTAB and proteinase K method. Thousands of Bulinus snails were examined using this extraction method.

In summary; PCR is ready for use in areas of low schistosomiasis endemicity for detecting both S. haematobium and S. mansoni infected snails. Only preliminary experiments are required for establishing its suitability with local snail species.

Zoonotic reservoirs of schistosomiasis in the Eastern Mediterranean Region and implications for transmission

The already known naturally-infected hosts for the two species of human schistosomes existing in the EM Region are all mammals. For S. mansoni, they belong to Placentals, with different orders Rodentia, Primates, Carnivora, Cetartiodactyla, Insectivora, Xenarthra; they belong also to Marsupials with the order Didelphimorphia. For S. haematobium, a smaller number of orders exist, they all belong to Placentals, with the orders Rodentia, Primates and Cetartiodactyla. The epidemiological tools available in the literature that ascertain that a host is infected are, firstly, the prevalence which is the number of infected hosts on the total number of hosts examined. There are two ways to ascertain if a host is infected: either by faecal examination or by post-mortem examination. In this last case, the worm burden is another parameter available. Then, for both faecal or post-mortem examination, the egg intensity is used; it is the number of eggs per gram of faeces and the last parameter associated to the egg intensity is the percentage of viable eggs, i.e. those which are going to be implicated in transmission.

The different orders found naturally-infected by S. mansoni are the Rodentia with two ubiquitous rodents, R. rattus and R. norvegicus with, in America, for R. rattus, high prevalence, high worm burden and high egg intensity but for R. norvegicus quite high prevalence and worm burden but an egg intensity of zero. In Africa and Middle-East, those two rodents also exist and are found naturally-infected by S. mansoni with epidemiological parameters smaller than in America. Several other different rodents were found in the American continent. For a great majority of these rodents, prevalences are high but another rodent, Cavia aperea, had an egg intensity of zero. In Africa and
Middle-East, different other rodents exist with epidemiological parameters lower compared to America. Primates were found both in America and in Africa and Middle-East with various prevalences. Carnivora were found both in America and in Africa. Cetartiodactyla were found in America and in Africa. Insectivora were only found in Africa. Xenarthra only in South America. Marsupials of the order Didelphimorphia only in South America. Regarding the EM Region, five orders of placentals were found; Rodentia with 4 species also found in Egypt, *Arvicanthus niloticus*, *Gerbillus pyramidum*, *Rattus rattus* and *Rattus norvegicus*. Naturally-infected *A. niloticus* were also found in Sudan and naturally-infected *R. rattus* were also found in Oman. Primates of the species *Papio hamadryas* were found naturally-infected in Saudi Arabia. Carnivora of the species *Canis familiaris* were found naturally-infected in Sudan with quite high prevalence but no eggs could be seen in the faeces. Cetartiodactyla were also found to be naturally-infected by *S. mansoni* in Sudan with low prevalence and no eggs in the faeces. Insectivora of the genus *Crocidura* were found in Egypt.

The implications of the presence of naturally infected animals on schistosome transmission, especially in low transmission areas

Low transmission areas may come from a switch between high transmission areas that became low transmission areas thanks to different control measures (TDR
Strategic Direction of Schistosomiasis). They may also come from the re-emergence of the disease in new areas either due to immigration of infected humans in zones free of parasites but harbouring the snail intermediate host or due to the presence of reservoir hosts. The growing interest towards these areas will permit to better understand the origin and maintenance of schistosomiasis in the world and will help us to develop a sustainable control of the disease. Two implications of the presence of reservoir hosts in an area exists: (i) the reservoir hosts may be responsible for re-emergence of schistosomiasis: in zones where human and rodent populations are mixed, and where some individuals, humans and rodents are infected, the total treatment of humans may be followed by a re-emergence of the disease, the life cycle of the schistosome being maintained by the reservoir host; (ii) the reservoir hosts may be responsible for an enhanced pathology towards humans: in zones where humans and rodents do not mix, a human treatment occurs and by the time, after several generations, the parasite adapts itself to the reservoir host and gets some specific life-history traits different from the initial population; then if, for any reason, a contact is made between humans and the reservoir hosts, humans may be infected by a parasite that may be more pathogenic.

Finally, the following are some propositions concerning the control of reservoir hosts:

- search for reservoir hosts;
- training to trap potential reservoir hosts and to identify them; training to collect the epidemiological data: prevalence, worm burden, egg intensity and egg viability;
- modify the transmission areas in order to separate humans from the environment occupied by the reservoir host by building latrines, washing areas and recreation of safe areas.
Meeting Recommendations

The participants noted and appreciated different effective measures taken by the Schistosomiasis Control Programmes (SCP) in member states of the Eastern Mediterranean Region that led to the current situation of low transmission and adopted the following recommendations. The SCP managers are requested to:

1. Prepare and have available for review detailed protocols for (i) surveillance (including parasitological and serological methods); (ii) snail/infected snail detection; (iii) mollusciciding; (iv) case detection (v) population based chemotherapy.

2. Take necessary steps for verification and validation of low transmission (or zero transmission) by more efficient, rigorous, sensitive and specific methods. Serological, antibody detection, methods are to be used for testing endemic residents and, molecular methods for testing snail intermediate hosts (in the near future the use of serology will be piloted in Morocco and parts of Saudi Arabia and Syria and will help inform future practice in other areas).

3. Investigate, in depth, residual transmission foci in hotspot areas and adapt respective strategies accordingly.

4. Determine the existence of natural animal reservoir host(s) for S. mansoni and, if present, evaluate their significance especially in areas with residual transmission (in the near future this will be investigated in Oman and Libya in particular).

5. Enforce current control activities in low-transmission areas in order to achieve elimination of schistosomiasis.

6. Initiate and maintain surveillance activities to detect possible resurgence/re-introduction of schistosomiasis infection (to sample within traditional transmission areas, non-traditional but “at risk” areas and, where appropriate potentially infected immigrants).

7. Prepare the programme for evaluation of interruption of transmission as a prerequisite step aiming for certification of elimination.
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