Human Schistosomiasis in the Middle East and North Africa Region

Rashida Barakat, Hala El Morshedy, and Azza Farghaly

Contents

Abstract Human schistosomiasis is one of the most common Neglected Tropical Diseases (NTDs); it is an intravascular parasite caused by the trematode blood fluke (*Schistosoma*). Most human infections are caused by *S. haematobium*, *S. mansoni*, and *S. japonicum*. An estimated total of 237 people are infected worldwide, and 732 million people are at risk of being infected. In the Middle East and North Africa (MENA) Region alone, 12.7 million individuals are infected. The link between poverty and high prevalence is evident, where approximately ten million of infected individuals are clustered in Egypt and Yemen. However, during the past 20 years significant changes had occurred in the region. Schistosomiasis was eliminated from Islamic Republic of Iran, Oman, Lebanon, and Tunisia. Transmission has been greatly reduced in Egypt, Morocco, Saudi Arabia, Iraq, Jordan, and Syria. Evidence from the Egyptian experience indicated that a nonintegrated intervention strategy,

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such as annual drug delivery for morbidity control, did not succeed to alter transmission.

Large-scale mass chemotherapy is the first step to reducing the burden of *Schistosoma*-related disease; yet, such programs may not significantly alter parasite transmission in high-risk areas. Snail control, integrated with drug treatment proved to be most efficacious in preventing and controlling schistosomiasis in Saudi Arabia, Morocco, and Egypt. Intersectoral collaboration between health, agriculture, and education is an extremely important part of advocacy in any program and is an essential part of any successful program in countries which achieved elimination or near elimination progress. This necessitates political commitments for decades. Despite the notable success in schistosomiasis control in the region, achievements are jeopardized by the current political instability, therefore resurgence of high prevalence, high intensity of infection, and severe morbidity might ensue.

Yemen is the only country in the Middle East not to have eliminated the disease. The significant World Bank funds being allocated to the 6-year control program in Yemen will continue provided the political situation there returns to a level that allows drug distribution.

Keywords Human schistosomiasis • The MENA Region • Epidemiology • Control

Human Schistosomiasis

Human schistosomiasis is one of the most common NTDs; it is an intravascular parasite caused by the trematode blood fluke (*Schistosoma*). Most human infections are caused by *S. haematobium*, *S. mansoni*, and *S. japonicum*; less prevalent species include *S. mekeongi* and *S. intercalatum*. Schistosomiasis is endemic in 77 countries in tropical and subtropical regions; estimates of infected individuals worldwide are 237 million; another 600–779 are at risk of being infected (Chitsulo et al. 2000; Steinmann et al. 2006; WHO Weekly Epidemiological Report 2012). The life cycle of the parasite is characterized by alteration of generation; asexual reproduction occurs in the snail intermediate host and sexual reproduction occurs in humans (Fig. 1). The pathology of schistosomiasis is due to egg-mediated immune response in the form of granuloma formation followed by fibrosis which results in obstructive manifestations in the gastrointestinal tract (GIT) in case of intestinal schistosomiasis and in the urinary tract in the case of *S. haematobium* (Nash et al. 1982; Wynn et al. 2004; Wilson et al. 2007). However, eggs can be disseminated to other organs, e.g., the brain, the spinal cord, genital organs, and the lungs leading to severe morbidity (Gryseels et al. 2006). Squamous cell carcinoma is one of the serious complications of urinary schistosomiasis in Egypt and North Africa (Fedewa et al. 2009). In infected children, studies of physical and intellectual functions indicate significant reductions in physical fitness and spontaneous activity

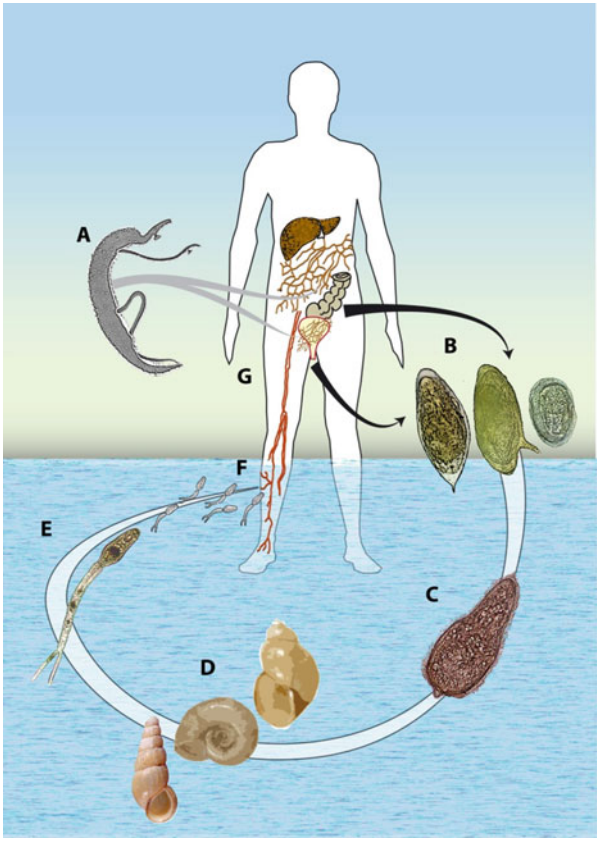

Fig. 1 Life cycle of human schistosomiasis (A) adult worms, (B) eggs (left to right, *S. haematobium*, *S. mansoni*, *S. japonicum*), (C) miracidium, (D) intermediate snail host (left to right, *Oncomelania*, *Biomphalaria*, *Bulinus*), (E) cercaria. Used with permission from the Institute of Tropical Medicine Antwerp

among children (Latham et al. 1990). Linear growth and nutrition are impaired, resulting in stunting and underweight status among infected children (Assis et al. 1998; Coutinho et al. 2006). Poor performance in standardized intelligence and achievement tests has also been associated with schistosomiasis (Nazel et al. 1999; Jukes et al. 2002; Ezeamama et al. 2005, 2012).

Overview of the Middle East and North Africa Region

The MENA Region includes 21 countries inhabited by 336.5 million people (Fig. 2). Population density in MENA accounts for 5 % of the world's total population. The highest density is found in Egypt (82 million), followed by Iran (75 million), Algeria (36 million), Morocco and Iraq (31–32 million each), Kingdom of Saudi Arabia (KSA) (26 million), and Yemen (25 million) (Population Reference Bureau 2013).

Fig. 2 Map of countries in MENA Region. Modified, with the permission of the publisher, from Roy "*IFM: MENA Region Recovering with 4.5 % Growth in 2010,*" Offshore Capitalist, 2010 (http://offshore-capitalist.com/2010/04/imf-mena-region-recovering-with-4-5-growth-in-2010/)

Both *S. mansoni* and *S. haematobium* are endemic in the Region; approximately 12.7 million individuals are infected. However, distribution of infected cases is not uniform; the largest number of cases occur in Egypt (7.2 million), followed by Yemen (2.9 million), Algeria (2.3 million), and Libya (0.3 million) (Hotez et al. 2012). The Eastern Mediterranean Region ranked second after the Sub-Sahara African Region according to the number of individuals requiring preventive chemotherapy for schistosomiasis (14,493,641); however, only 2,137,787 cases were given treatment in 2010 (WHO Weekly Epidemiological Report 2012). Clustering of infected cases in a few countries of the Region is due to a low level of socioeconomic standards including poverty, bad environmental sanitation, and high population density. Estimates since 2011 indicate that 2.4 % of the population lives below the World Bank poverty figure of US$1.25 per day and 12 % lives below US$2 per day. It is noteworthy that most of the countries in the Region are classified by the World Bank as low-middle income countries (World Bank (n.d.) Data:Middle East and North Africa).

However, during the past 20 years significant changes have occurred in the Region. Schistosomiasis was eliminated from the Islamic Republic of Iran, Oman, Lebanon, and Tunisia. Transmission has been greatly reduced in Egypt, Iraq, Jordan, Morocco, Saudi Arabia, and Syria, while in Yemen schistosomiasis is considered a major health problem (Table 1 and Fig. 3) (Fenwick et al. 2006; Rollinson et al. 2012; International Association for Medical Assistance to Travelers 2012). In this chapter the focus will be on countries with a large population size which achieved notable progress in the control of schistosomiasis, e.g., Egypt, Morocco, and Saudi Arabia, and countries where schistosomiasis has remained as a major health problem such as the Yemen.

Table 1 Condition of schistosomiasis in MENA Region according to country

Country	Condition	Snails
Algeria	*S. haematobium* is absent from most of the country, risk of infection is localized in the province of Boumèrdes	*B. truncatus*
Egypt	Both species are endemic; *S. haematobium* is endemic throughout southern Egypt including Fayoum. *S. mansoni* is endemic in the Nile Delta and Suez Canal Region. There are limited foci in southern Egypt. Control activities have reduced the infection; estimated prevalence in 2003 is <3 % in most villages and 0.3 % in 2012	*B. truncatus* *B. alexandrina*
Iran	*S. haematobium* is eliminated	*B. truncatus*
Iraq	*S. haematobium* is present along the Euphrates and Tigris river system, estimated prevalence in 2003 and 2010 is 0.1 %	*B. truncatus*
Jordan	Eliminated, non-endemic	–
Lebanon	*S. haematobium* elimination was declared	*B. truncatus*
Libya	Both *S. haematobium* and *S. mansoni* are endemic. Areas of risk are limited and specified in: 1. Near the Mediterranean coast in Darnah and in oasis south of Misratah. 2. In the central part of Fezzan. 3. Near the southwestern border of Algeria. Estimate of prevalence in 2003 and 2010 is 5 %	*B. truncatus* *B. globsus* *B. alexandrina*
Morocco	Transmission of *S. haematobium* is interrupted based on serological study of the remaining low risk foci	*B. truncatus*
Oman	*S. mansoni* is absent from most of the country, estimated prevalence in 2003 and 2010 is 0.1 % and 0.01 % respectively	*B. alexandrina*
Saudi Arabia	Both S. *haematobium* and *S. mansoni* are endemic. Control has reduced the infection to 0.1 % in 2003 and 0.02 % in 2010. Areas of risk are restricted to Asir in the southwestern region	*B. truncatus* *B. buccarii* *B. wright* *B. phfeifferi*
Syria	*S. haematobium* low risk areas are located along the river system in the northern parts of the country. Estimated prevalence in 2003 and 2010 is <0.1 % and <10 %, respectively	*B. truncatus*
Tunisia	Elimination of *S. haematobium* was declared	*B. truncatus*
Turkey	Eliminated, non-endemic	–
Yemen	Both *S. haematobium* and *S. mansoni* are endemic in the whole country including urban communities, estimated prevalence in 2003 and 2010 is 14.6 % and 14.3 %, respectively	*B. truncatus* *B. phfeifferi* *B. alexandrina*

Human Schistosomiasis in Egypt

History

The history of urinary schistosomiasis in Egypt is long-standing, i.e., since the time of ancient Egypt. The first description of the disease was found in Kahun papyrus (1900 B.C.) referring to hematuria as a manifestation of a disease known as a-a-a disease (Shokeir and Hussein 1999) (Fig. 4). The parasite etiology of the disease is proposed in the Ebers papyrus in (1550 B.C.), while the eggs of *S. haematobium* have been

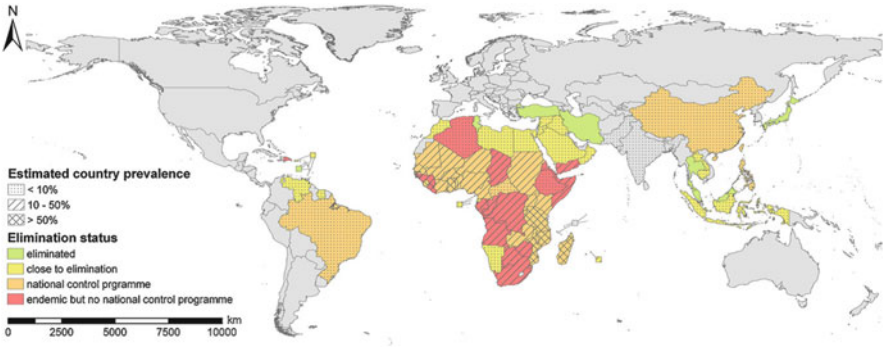

Fig. 3 World map, highlighting countries where schistosomiasis has been eliminated (*green color*), is close to elimination (*yellow color*), ongoing control program (*orange color*). *Red color*, where schistosomiasis is endemic, but national control programs have yet to be implemented. *Hachure* indicate prevalence in countries, *pointed hachure* (low prevalence <10 %), *dashed hachure* (moderate prevalence 10–50 %), and *crossed hachure* high prevalence >50 %). Reprinted from (Rollinson et al. 2012) Copyright (2012), with permission from Elsevier

Fig. 4 Hieroglyphic script of haematuria referring to schistosomiasis (a-a-a disease) as it appears in the Kahun papyrus. From http://www.scribd.com/doc/16105584/Urology-doc-Circumcision

found in the tissues taken from mummies of the twentieth dynasty, 1250–1000 B.C. (Ruffer 1910; Ebbel 1937). The morbidity of urinary schistosomiasis was mentioned in the Chester Beatty papyrus describing bladder cancer as a disease complication (Badr 1981). The causative organism was termed *Bilharzia* after Theodor Bilharz, who described the parasite from human autopsy in Kasr El Ainy hospital in Cairo in 1851 (Bilharz 1853). The discovery of the life cycle and presence of both *S. haematobium* and *S. mansoni* in Egypt was first reported by Leiper (1915). Recently, in the early 1990s, Schistosome antigens were detected in tissues from mummies using the ELISA technique (Deelder et al. 1990; Miller et al. 1992).

Distribution of Schistosome Species in Egypt

The comprehensive epidemiology of schistosomiasis was first described by Scott (1937). He mapped the distribution of both *S. haematobium* and *S. mansoni* in the Nile Delta representing Northern Egypt and the Nile Valley representing Southern Egypt. The Nile Valley comprises Middle Egypt which extends from Giza to

Fig. 5 Map of Egyptian Governorates. Food and Agriculture Organization of the United Nations, 2011, Mohamed A. El-Nahrawy, Country pasture/Forage Resource Profile. http://www.fao.org/ag/AGP/AGPC/doc/Counprof/PDF%20files/Egypt.pdf. Reproduced with permission

Menya Governorate and Upper Egypt extending from Assiut to Aswan. *S. haematobium* was endemic throughout Egypt; prevalence in the Nile Delta and in the parts of the Nile Valley with perennial irrigation was high (60 %), while low prevalence (6 %) was reported in regions of basin irrigation in the Nile Valley. Distribution of *S. mansoni* was limited to the Delta region; prevalence was high (60 %) in the northern and eastern parts of the Delta, whereas low prevalence (6 %) occurred in southern parts of the Delta (Fig. 5).

The snail intermediate host of *S. mansoni* and *Biomphalaria alexandrina* was abundant in the Nile Delta only, whereas *Bulinus truncatus*, the snail intermediate host of *S. haematobium*, was found in the Nile Delta and the Nile Valley; its density was higher in areas of the Valley experiencing perennial irrigation than in areas with basin irrigation. The breeding places of snails were swept by the annual flood of the River Nile and desiccated during the hot summer in areas of basin irrigation resulting in interruption of disease transmission. Accordingly, Scott concluded that a shift to perennial irrigation in parts of the valley resulted in high prevalence of *S. haematobium*. Similarly, several studies confirmed that a shift to perennial irrigation was associated with high prevalence of *S. haematobium* in the Nile Valley as far as Nouba, the farthest south in Upper Egypt (Azim 1935; Khalil and Azim 1938; El-Zawahry 1964).

Twenty years after Scott, there was a dramatic increase in the prevalence of *S. haematobium* in Sohag, Qena, and Aswan Governorates in Upper Egypt coinciding with the shift to perennial irrigation; meanwhile, *S. haematobium* had decreased in other parts of the valley. On the other hand, *S. mansoni* had increased in Giza Governorate. As for the Nile Delta, both *S. haematobium* and *S. mansoni* had decreased as compared to the results of Scott's comprehensive survey (Wright 1973). Thereafter, the changing pattern of schistosomiasis in Egypt continued, while *S. haematobium* decreased from the Nile Delta; *S. mansoni* demonstrated relative increase. Extension of *S. mansoni* to Upper Egypt was documented in Menya, Assiut, and Fayoum (Cline et al. 1989; Abdel-Wahab et al. 1993; Michelson et al. 1993; El-Enien et al. 1993; Medhat et al. 1993).

In1983, a cross-sectional study of 71 villages of the Nile Delta demonstrated a sharp decline in the prevalence of *S. haematobium* from 56 % to 5 %; meanwhile, there was a variable increase in the prevalence of *S. mansoni* in all the Nile Delta Governorates. *S. mansoni* had increased twofold in Menoufeya Governorate from 10 % in 1935 to 20 % in 1983 (Cline et al. 1989). A recent comprehensive survey implemented in 1990, including the same 71 villages, further confirmed that *S. mansoni* has replaced *S. haematobium* in the Nile Delta. However, there was an overall 38 % reduction in the prevalence of *S. mansoni* as compared to the 1983 survey. The observed decline in prevalence was attributed to availability of the praziquantel (PZQ) chemotherapy (Cline et al. 1989; Michelson et al. 1993). In the Nile Valley governorates, *S. haematobium* decreased except in Sohag, Qena, and Aswan (Miller et al. 1981; El-Khoby et al. 2000a).

In 1990, a comprehensive house-to-house survey covered 251 villages from 9 governorates representing the Nile Delta, and the Nile Valley was implemented by the epidemiology teams of the Schistosomiasis Research Project (SRP) (El-Khoby et al. 2000b). The results demonstrated an average *S. mansoni* prevalence of 36.45 %, while *S. haematobium* vanished from most of the governorates. The highest prevalence was reported from Ismailia, Suez Canal zone (1.8 %), and the lowest was in Qalubia (0.08 %) (Barakat et al. 1995; Habib et al. 2000; El-Hawey et al. 2000; Abdel-Wahab et al. 2000; Nooman et al. 2000). In Upper Egypt, the average prevalence of *S. haematobium* was 7.8 %, while the highest prevalence was 13.7 % and the lowest prevalence was 4.8 %. On the other hand, *S. mansoni* was rare, except in Fayoum where the recorded prevalence was 4.3 % (Abdel-Wahab et al. 2000; El-Khoby et al. 2000a; Hammam et al. 2000a, b).

An Update of the Epidemiology Profile of Human Schistosomiasis in Egypt

The SRP encompassed 89,180 individuals from 251 villages representing rural communities in Egypt. The project provided estimates of prevalence and intensity of infection of both Schistosome species, evaluated risk factors, investigated morbidity for the first time using portable ultrasonography and documented changing patterns of schistosomiasis in Egypt. *S. haematobium* infection was clustered in

Upper Egypt, prevalence of infection ranged from 4.8 % in Qena to 13.7 % in Fayoum. Overall, infection peaked at 15.7 % among the age group 10–14 years; males were 1.9 times more infected than females. The average intensity of infection was below 10 eggs per 10 ml of urine and ranged from 1.53 eggs to 9.95 eggs per 10 ml of urine; the intensity of infection was higher among males in all age groups. The force of infection was higher in ezbas (hamlets) than in large villages, due to poverty, lack of potable water supply, bad environmental sanitation and inaccessibility to health services which are more common in ezbas than in large villages. Microscopic hematuria increased the risk of infection (OR = 12.4). Among infected cases, bladder lesions were detected in 2 % only, whereas first grade periportal pipe stem fibrosis (PPF) and splenomegaly were found in 14.7 % and 13.4 % respectively (Abdel-Wahab et al. 2000; El-Khoby et al. 2000a; Hammam et al. 2000a, b).

The overall prevalence of *S. mansoni* in the Nile Delta and Ismailia (Suez Canal zone) was 36.4 %. The highest prevalence was in Ismailia Governorate (42.9 %), followed by Kafr El-Sheikh (39.2 %), Menoufeya (28.5 %), and the least in Qalubia (17.5 %). Infection peaked at 48.3 %; males were 1.6 times as likely to be infected as females. The overall intensity of infection was below 100 eggs per gram of stool (epg) and ranged from 62.6 epg in Qalubia Governorate to 93.3 epg in Ismailia Governorate. Similar to *S. haematobium* individuals living in ezbas were at higher risk of becoming infected (OR = 1.9) as compared to those living in large villages. Examination with portable ultrasonography demonstrated splenomegaly in 20.8 % while grade II and grade III PPF was found in 50.3 % (Barakat et al. 1995; El-Khoby et al. 2000a; El-Hawey et al. 2000; Habib et al. 2000; Abdel-Wahab et al. 2000; Nooman et al. 2000).

The results of the SRP comprehensive survey representing schistosomiasis endemic communities in Egypt provided accurate data about the epidemiology profile and changing pattern of schistosomiasis, while *S. haematobium* continues to decline sharply in the Nile Delta, *S. mansoni* transmission is continuing at an appreciable level, in addition to evidence of extension of *S. mansoni* to Upper Egypt (Talaat et al 1999; El-Khoby et al. 2000a; Lotfy 2009; Barakat 2012). Moreover, the pattern of morbidity sequelae of *S. haematobium* has changed over the past 26 years. Transitional cell carcinoma of the urinary bladder has replaced the squamous cell carcinoma previously associated with a history of urinary schistosomiasis (Felix et al. 2008; Fedewa et al. 2009; Salem et al. 2011). Age and sex distribution of infection of this study is close to data of individual governorates in Egypt and elsewhere in other countries known to be endemic for schistosomiasis (El-Malatawy et al. 1992; Barakat et al. 2000; Raja'a et al. 2000; Gryseels et al. 2006; Mazigo et al. 2012). Predisposition to infection according to age and gender is due to socioeconomic behavioral, ecological, and biological factors which influence the interaction between human and animal hosts and life cycle stages of the parasite (Mazigo et al. 2012).

Observation of SRP data according to governorates demonstrated that Kafr El-Sheikh Governorate had a high prevalence of *S. mansoni*. The study sample from Kafr El-Sheikh included 18,168 individuals from 44 villages and ezbas. Individual analysis of data from Kafr El-Sheikh provides a better understanding

Fig. 6 Implantation of rice in an Egyptian village. Science Photo Library #E768/0409

of the epidemiology in hot transmission areas. At baseline, in 1990, the overall prevalence was 39.3 ± 3.3 %, and the intensity of infection was 72.9 ± 7.3 epg. The risk of infection was higher among males (OR = 1.4). Infection peaked at 55.4 ± 3.2 % at 16 years of age, and intensity of infection peaked at 81.5 ± 12.1 in the age group 10–14 years. Frequent water contact activities increased the risk of infection (OR = 3). Morbidity data based on sonographic examination demonstrated splenomegaly in 55 % and PPF in 47.25 %, both increased with age and the latter increased with history of bathing in canal water (OR = 51); from the 44 villages *S. haematobium* was diagnosed in 41 samples only (Barakat et al. 2000).

Variability of prevalence and intensity of infection were evident among villages and ezbas indicating focal pattern of disease transmission. The lowest prevalence was 24.5 % and the highest was 68.9 %. Intensity of infection ranged from 37.8 epg to 129.7 epg. The study showed that prevalence and intensity of infection were positively correlated (Barakat et al. 2000).

The overall high prevalence of *S. mansoni* in Kafr El-Sheikh Governorates relative to other governorates in the Nile Delta might be due to extensive cultivation of rice in Kafr El-Sheikh. The season of rice cultivation occurs at the peak of snail shedding during the hot months of summer. It also requires frequent daily contact with water during the implantation period where all ages and both sexes participate in rice planting. This season is considered as a sociocultural event where villagers share work in cultivating their land (Fig. 6). The association of rice cultivation and high prevalence and intensity of infection of *S. mansoni* was recently reported from Côte d'Ivoire (Yapi et al. 2005). The clustering of high intensity of infection in a small segment of population follows the nonrandom distribution of eggs (Kirtorn and Hiagashi 1985). On the other hand, the observed low intensity of infection was explained by the availability of PZQ passive chemotherapy. Variability in force of

infection between villages is due to variations in the socioeconomic standards and access to health services (Barakat et al. 2000).

In comparison to other studies in Kafr El-Sheikh Governorate in 1983 and 1990, a similar trend was observed for *S. haematobium* which continues to decline. However, the results for *S. mansoni* were variable, being 51 % in 1983 and 17 % in 1990. Comparisons of the three studies might be difficult because of differences in sample design (Kleinbaum et al. 1982). The high prevalence of the SRP study (39.2 %) as compared to the study done by Miller et al. 1978 (20 %) might be due to differences in the sensitivity of the diagnostic tool. In 1978 study, they used Merthiolate Iodine Formaldhyde Concentration technique (MIFC), while in SRP study, two Kato slides were examined from a single stool sample. The Kato Katz technique is more sensitive than MIFC technique due to examination of a large amount of stool (86 mg); also the Kato technique is a single-step technique without the potential of losing eggs as compared to MIFC which includes several steps such as sieving and centrifugation (Katz et al. 1972).

Influence of Aswan High Dam on the Epidemiology of Schistosomiasis in Egypt

The Aswan High Dam was constructed on the River Nile 7 km south of Aswan in 1967. Its impact on schistosomiasis transmission was controversial, while some authors underestimate the role of the High Dam (Miller et al. 1978); several studies have highlighted its role in changing the ecology of breeding habitat which favors flourishing of *B. alexandrina*, the snail intermediate host of *S. mansoni*. In summary these changes include (1) shift to perennial irrigation all through the Nile Delta and the Nile Valley, (2) changes in the water current velocity, and (3) absence of silt (Malek 1975; Abdel-Wahab et al. 1979; White 1988). It is noteworthy that reclamation of new areas in the desert and creation of the huge Lake Nasser led to mobilization of people from endemic areas thus creating new foci of transmission. In two new reclaimed areas in the desert close to Ismailia, prevalence of *S. mansoni* was 40 % and 49 % in 1992 (El-Sayed et al. 1995).

Despite the controversy in the analysis of epidemiological changes in human schistosomiasis after the construction of the High Dam, there has been a substantial decline of *S. haematobium* and an extension of *S. mansoni* to Upper Egypt. Although the density of *B. alexandrina* has increased, prevalence of *S. mansoni* has decreased due to ongoing control programs. The decline in *S. haematobium* all over Egypt is due to ecological changes created by the construction of the High Dam which interferes with the breeding of *B. truncatus* (Hotez et al. 2012). A cross-sectional study in Fayoum Governorate in 1991 showed that *S. mansoni* prevalence was 22.3 % while *S. haematobium* was 3.4 %; among *S. haematobium* infected cases there were only two children aged below 10 years. Reviewing records of Ministry of Health and Population (MOHP) demonstrated that *B. truncatus* has not been detected in local canals since 1986 and few uninfected snails were found between 1981 and 1985 (Abdel-Wahab et al. 1993). Therefore,

these data indicate that interruption of *S. haematobium* transmission is due to unfavorable breeding habitat for the snail intermediate host.

Environmental and demographic changes associated with the development of water resources might facilitate spread of schistosomiasis (Patz et al. 2001; Steinmann et al. 2006). *S. mansoni* was introduced into Senegal and Mauritania after the construction of Senegal River Dam. Ten years after the construction of the Daima Barage Dam in 1985, prevalence of *S. mansoni* ranged from 4.4 % to 43.65 % in the Delta (Picquet et al. 1996). In Ethiopia, introduction of large scheme irrigation projects resulted in the rapid increase of *S. mansoni* prevalence reaching up to 82 % four decades after the start of the project (Kloos et al. 1988; Simonsen et al. 1990). Similarly, construction of For Kossou and Toabo Dams in Côte d'Ivoire increased the prevalence of *S. haematobium* from 14 % to 53 %, while *S. mansoni* remained stable (De Clercq et al. 1999). It seems that changes in transmission of specific Schistosome species is linked to changes in the ecology of the breeding habitat of the snail intermediate host created by hydrological changes which follow construction of dams and irrigation projects.

Control of Human Schistosomiasis in Egypt

Before 1984, control projects in Egypt were planned to interrupt transmission regardless of the force of infection in endemic communities. Molluscicide and chemotherapy were the main components of all control projects. The largest of these was the Middle Upper control program which started in Middle Egypt in 1980 (Medhat et al. 1993; Talaat et al. 1999). The project was planned in three phase; (1) the intensive phase (wide application of molluscicide and chemotherapy, (2) consolidation phase (focal molluscicide and chemotherapy), and (3) maintenance phase. The impact of control activities was remarkable; prevalence of *S. haematobium* decreased from 30 % to 6.5 %. However, reinfection rates were high especially among young children (Kessler et al. 1987; Webbe and El-Hak 1990).

In 1990, the National Schistosomiasis Control Program (NSCP) adopted the strategy of morbidity control according to the new WHO strategy declared in 1980s (WHO 1985). The discovery of PZQ, as a safe drug, given in a single oral dose and effective for all human Schistosome species and the availability of the Kato technique as a sensitive diagnostic test easily processed under field conditions justified the shift to morbidity control. At the beginning of the program, selective chemotherapy was offered through passive and active case finding. In 1997, mass chemotherapy was offered to all children enrolled in schools (aged 6–18 years) and to all villages with prevalence of $\geq$20 %, in addition to focal molluscicide, health education, and capacity building of personnel in rural health units. The threshold of mass chemotherapy was further reduced to $\geq$10 % in 1999, $\geq$5 % in 2000, $\geq$3.5 % in 2002, and to $\geq$3 % in 2003 (WHO 2011). These values are much lower than the recommended WHO regulations (Table 2). Since 1990, more than 50 million doses of PZQ were offered (Rollinson et al. 2012).

Table 2 WHO recommendation for preventive chemotherapy

Prevalence thresholds for schistosomiasis intervention
If prevalence of infection ≥50 % (high-risk community)
Treat all School-age children and other at risk groups once a year
If prevalence of infection ≥10 % and ≤50 % (moderate-risk)
Treat all School-age children and other at risk groups once every 2 years
If prevalence of infection <10 % (low-risk)
Treat all School-age children twice in childhood, and symptomatic cases in health facilities

Modified, with the permission of the publisher, from the "*Report of an Informal Consultation on Schistosomiasis Control*," World Health Organization 2011. (http://apps.who.int/iris/bitstream/10665/78066/1/9789241505017_eng.pdf)

In 1997 before the implementation of mass chemotherapy, an independent team evaluation for NSCP activities was conducted in Kafr El-Sheikh Governorate. A representative sample of 8000 individuals from four high prevalence villages (≥40 %) and four low prevalence villages (≤31 %) was investigated (Barakat et al. 1998). From 1991 to 1993, the SRP epidemiology team of Kafr El-Sheikh Governorate led the morbidity control by means of selective annual chemotherapy, while from 1993 to 1997, NSCP morbidity control measures solely were operating. A significant drop in prevalence and intensity of infection was achieved in all villages in 1993 after two rounds of selective chemotherapy offered by the epidemiology team. In 1997, the downward trend of prevalence was maintained in low prevalence villages; however, an upward increase in prevalence was observed for high prevalence villages, though still lower than the baseline prevalence in 1991 (Table 3) (Barakat et al. 1995, 1998). A very close prevalence was reported for Alexandria Governorate in 1998. A parasitological survey of stool from 3,281 individuals living in rural communities was undertaken to investigate the prevalence of schistosomiasis in this area. The results revealed that prevalence of *S. mansoni* accounted for 20.5 %, with low intensity of infection, and increased with age to reach a maximum of 40–46.3 % at 15–30 years of age. Intensity of infection followed the same pattern (Zaki et al. 2003). At this level of prevalence, selective chemotherapy offered to some of the infected population was not enough to maintain the downward trend in prevalence, indicating that mass treatment and percentage of chemotherapy coverage have to be considered (Wang et al. 2012). According to the World Health Assembly Resolution (WHA 54.19) held in May 2001, the minimum target is to cover 75 % of school children at risk by 2010 (WHO 2001).

The impact of mass chemotherapy adopted by the NSCP was substantial; overall prevalence of *S. mansoni* decreased from 16.4 % in 1988 to 4.2 % in 2000. Similarly, *S. haematobium* prevalence decreased from 11.9 % to 3 % during the same period (El-Khoby et al. 1998; Fenwick et al. 2003). Since 2003, a multisectoral approach involving mass and selective chemotherapy tailored to the force of infection, focal molluscicide, health awareness and environmental sanitation, and surveillance was adopted, aiming to interrupt transmission. In villages with prevalence ≥3 %, mass chemotherapy, focal molluscicide, potable water

Table 3 Prevalence of *S. mansoni* in high and low prevalence villages in Kafr El-Sheikh Governorate 1991–1997

	Prevalence of *S. mansoni*			
Village prevalence	1991 (baseline)	1992	1993	1997
Low	30.3	26.4	20.5	17.3
High	44.9	28.8	19.5	19.8

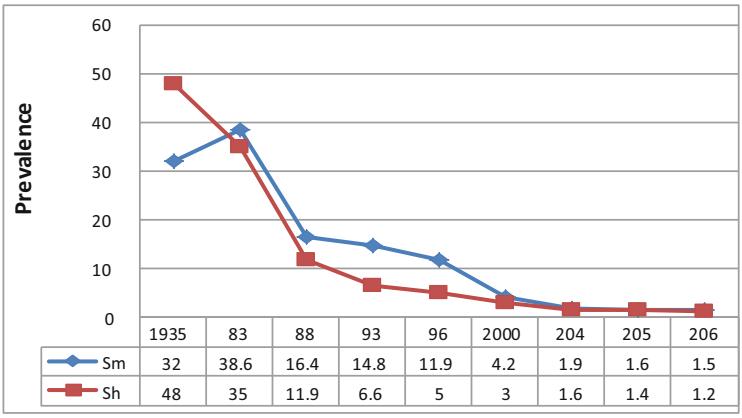

Fig. 7 Overall prevalence of schistosomiasis in Egypt, during the period 1935–2006, Modified, with the permission of the publisher, from the "*Report: Inter-country Meeting on Strategies to Eliminate Schistosomiasis from the Eastern Mediterranean Region*, World Health Organization 2007 (http://www.who.int/schistosomiasis/resources/EMRO_report_Schistosomiasis.pdf)

provisioning, and environmental sanitation were implemented. In villages with prevalence <3 %, the approach was limited to selective chemotherapy, focal molluscicide, and environmental sanitation. In 2006, the overall prevalence of *S. mansoni* was 1.5 % and that of *S. haematobium* was 1.2 % (Fig. 7) (WHO 2007). In 2010, according to records of MoHP, there were only 20 villages in the whole country with a prevalence of more than 3.5 % and all were <10 % (WHO 2011).

Rollinson et al. (2012) emphasized that elimination must be seen as the extreme end of the control spectrum and not as a new goal by any means. The intersectoral approach between health, education, and agriculture guarantees the success of elimination programs (Holveck et al. 2007; Aagaard-Hansen et al. 2009). It is estimated that, in order to achieve elimination, the control program has to be sustained efficiently for 10–20 years (Curtale et al. 2010). However, morbidity sequelae may remain for decades. Endoscopic and histopathological study during the period from 2004 to 2009 covering 984 individuals aged 18–65 years presented with GIT manifestations demonstrated typical schistosomiasis colorectal lesions in 20.33 % of them (Gad et al. 2011). Serious complications such as hepatic decompensation, hypersplenism, and cor pulmonale are becoming rare. Therefore, in addition to field monitoring of infection and treatment outcomes, complete accurate longitudinal morbidity hospital-based data are paramount to document the success of control program.

Since the late 1980s, PZQ remains the mainstay in schistosomiasis control in all endemic countries, yet the drug is only effective against mature infection (Cioli and Pica-Mattoccia 2003). Drugs effective against premature infection such as artemether—an anti-malarial drug—will act in synergism with PZQ to interrupt transmission. Such a combination might be applicable in Egypt for two reasons; (1) difficulty in sustaining focal molluscicide because of such a complicated irrigation scheme, and (2) Malaria is not a major health problem in Egypt. The impact of artemether has been investigated in a double blind randomized control trial involving 913 school-age children from hot transmission villages in Kafr El-Sheikh Governorate. At the end of the study, incidence of *S. mansoni* was 2.8 % among the artemether group compared to 6.5 % among the group that offered PZQ only (WHO-EM/TDR/007/E/12.04/2500, 2001-2002).

The success of the control program in Egypt so far is the outcome of sequential planned processes based on countrywide precise mapping of endemic communities, followed by integrated control strategies tailored to local situations and supported by political commitments in addition to mobilization of international funds. Currently, political instability in Egypt might hinder the sustainability of NSCP achievements; moreover, resurgence of high indices of transmission and a greater disease burden cannot be excluded.

Human Schistosomiasis in Morocco

History

Morocco is a Northern African country, bordering the North Atlantic Ocean and the Mediterranean Sea. In 2010, the population size was approximately 32 million. Urinary schistosomiasis is the only form of schistosomiasis in Morocco; it was introduced into Morocco from Egypt or Sub-Saharan Africa (WHO 1993). The first case of urinary schistosomiasis was reported from Marrakesh Province in 1914 (Doumenge et al. 1987).

Epidemiology

Foci of transmission were mainly limited to the southern part of the country especially in the oases along the pre-Saharan belt (Barneoud and Carrosse 1929; Barneoud 1932; Connet 1937; Gaud and Maurice 1946). However, in 1970, spread of infection to other areas in the central and northern parts of Morocco was associated with the establishment of irrigation projects in the late 1960s (Benmansour 1970; Laaziri and Benouna 1982; Khallaayoune et al. 1998a). Throughout Morocco transmission of schistosomiasis was maintained by the snail intermediate host *B. truncatus*, which is more abundant during summer leading to an increase in the intensity of transmission (Khallaayoune et al. 1998b).

Schistosomiasis is patchily distributed in Morocco. Before the implementation of control programs, the disease was endemic in 20 provinces and the rate of infection reached up to 50–60 % in the early 1980s (WHO 1987a, b). Following recreational and domestic activities, infection peaked among school-age children (Khallaayoune and Laamrani 1992; Watts et al. 1998).

Control

The National Program of Schistosomiasis Control (NPSC) started in the early 1970s following the spread of schistosomiasis to the central and northern parts of the country; it was fully implemented in 1982. Strategies of control included; (1) active and passive treatment of infected cases in schools and villages by mobile and local teams. Until 1986, infected cases were treated with metrofonate, thereafter PZQ was introduced, offered as a single oral dose of 40 mg/Kg, (2) Niclosamide focal molluscicide, (3) health education programs in schools and villages, (4) intersectoral collaboration between health, education, and agriculture (Laamrani et al. 2000; Amarir et al. 2011).

From 1982 through 1997, the impact of the program was remarkable, overall prevalence decreased from 6.2 % to 0.3 %. Annual incidence was also reduced from 8.2/1000 to 1.3/1000. Moreover, there was a shift in the age specific infection rate among children aged 7–14 years; they represented 38 % of the total infected cases in 1996 as compared to 67 % in 1983 (WHO 1987a; Laamrani et al. 2000; Amarir et al. 2011).

The encouraging results of the NPSC lead to upgrading control strategies for elimination. The strategy of elimination was planned in stages with a target date for each province, the final to be reached in 2004 (Ministry of Health 1998). By 1999, the program was successful in 17 provinces (DELM 1999) and continuous decline of *S. haematobium* was evident from 1994 through 2006 (WHO 2007) (Fig. 8). In 2008, serological evidence of interrupted transmission was reported; 2,382 sera from children aged 1-16 years selected from the remaining endemic foci were tested to detect *S. haematobium* specific antibodies and all were negative (Amarir et al. 2011). Further longitudinal studies monitoring specific antibody titers can provide important information about the history of interruption of schistosomiasis transmission (Rollinson et al. 2012).

In conclusion, operational decentralization, integrated control strategies within the existing health services, and the intersectoral approach made achievement of the eradication goal feasible in Morocco (Rollinson et al. 2012). However, threats of resurgence cannot be ignored because the snail intermediate host is prevalent in the country. This necessitates carefully planned surveillance at the micro-level to maintain the success of the eradication program.

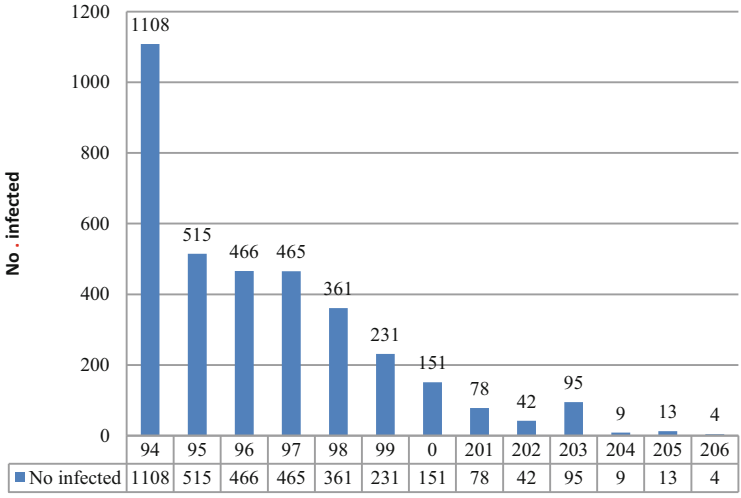

Fig. 8 Number of infected individuals with *S. haematobium* in Morocco during the period 1994–2006. Modified, with the permission of the publisher, from the "*Report: Inter-country Meeting on Strategies to Eliminate Schistosomiasis from the Eastern Mediterranean Region*, World Health Organization, 2007 (http://www.who.int/schistosomiasis/resources/EMRO_report_Schistosomiasis.pdf)

Human Schistosomiasis in Saudi Arabia

History

The Kingdom of Saudi Arabia (KSA) is one of the largest Arab countries of the Arabian Peninsula; it covers about 80 % of the Region. Geographically Saudi Arabia includes 6 regions; Eastern, Central, Northern, Northwest, Midwest, and Southwest regions; these regions are comprised of 13 provinces (Fig. 9). The population size amounts to 26 million. KSA has a high income economy based entirely on oil; however, agricultural economy has been expanding since the late 1970s due to development of new dams and irrigation projects. Schistosomiasis has been endemic in the Arabian Peninsula since the tenth century; Ibin Sina (Avi Cenna) described hematuria in his Medical texts (Alio 1967). From 1903 to 1961, schistosomiasis was reported from 12 provinces, the highest prevalence was found in the southwestern region. To date the eastern region is free from schistosomiasis (WHO 1987b; Al-Madani 1990).

Epidemiology

Both *S. haematobium* and *S. mansoni* are endemic in KSA, *S. mansoni* is mainly found in the high land of the western region, and *S. haematobium* is mainly reported

Fig. 9 Kingdom of Saudi Arabia map showing the 13 provinces. From mapsopensource.com (http://www.mapsopensource.com/saudi-arabia-map.html)

from Tabouk in the Northwest and from Baha and Mahael in the Low Land of the coastal plain in the Southwest region (Arfaa 1976; WHO 1987b; Ghandour et al. 1997, 1999; Shati 2009). Transmission of schistosomiasis is mediated by *B. pfeifferi* for *S. mansoni* and *Bulinus* species for *S. haematobium* (Magzoub and Kasim 1980; Ghandour et al. 1986, 1990); *B. truncatus*, *B. baccarii*, and *Bu. wrighti* have been reported as intermediate hosts for *S. haematobium* (Arfaa et al. 1989). Species specific gene markers have been used successfully to identify *Bu. truncatus* and *Bu. baccarii* collected from Asir, in the Southwestern region of KSA. Multiplex single step PCR helps to identify snails and to detect infection with *Schistosoma* species (Mostafa et al. 2012). Genetic variations of *Schistosoma* strains do exist at local, regional, and international levels, while Egyptian strains of *S. mansoni* are closely related to Saudi strains; Puerto Rican strains are clustered in different groups (Saoud 1966; Taylor and Nelson 1971; Voge and Mansour 1980; Fletcher et al. 1981, Jamjoom 2006).

The first comprehensive human and snail study was implemented by Alio 1967; the estimated prevalence of human schistosomiasis was 17 %; both *S. haematobium* and *S. mansoni* were endemic in the country except in the Eastern Region. Results of an extensive survey of the Ministry of Health in 1971 indicated that the disease is endemic in 12 regions at a prevalence ranging from 5 % to 20 % (Ashi et al. 1989). Arfaa in 1976 reported that transmission of schistosomiasis is only limited to a few foci in rural areas, and the disease is rare in large cities, e.g., Riyadh, Jeddah, Mecca, Taif, and Tabouk. He concluded that the snail habitats—which consist of wells, small canals, cisterns, small swamps, interrupted streams, and ponds—create

a special type of transmission which can be defined as "oasis transmission," making control of the disease both simple and practical. However, the agricultural irrigation projects and construction of new dams have led to creation of permanent breeding habitats for the snail intermediate hosts over a wide region of KSA (Ghandour et al. 1986, 1990).

Recently, details of human infection were delineated in a study done in 2004; results showed that Saudis accounted for 61.2 % of total infected cases and infection peaked at 15–39 years, providing evidence about the endogenous source of infection. Infection by gender showed that males were four times more infected than females. Overall, *S. mansoni* represented 75 % of total infections. Prevalence was highest in most of southwestern region with a focus in Hail in the North. *S. haematobium* was limited to a few foci in the southwestern region in Jazan and Asir, both provinces bordering Yemen, where transmission of schistosomiasis is going on at an appreciable level. Ministry of Health statistical data in 2008 confirmed that Saudis are more infected than non-Saudis; the percentage of infection was 55.5 % and 45.5 % for Saudis and non-Saudis, respectively (Saudi Arabia Ministry of Health 2004, 2008). A morbidity study based on endoscopic and histopathology examination of samples collected from 2,458 individuals with GIT manifestations during the period from March 1979 through December 1988, revealed typical *S. mansoni* lesions in 8.8 %. Their ages ranged from 11 to 72 years. Another eight patients had schistosomal polyps (Mohamed et al. 1990). These values are lower than other countries in the Region where schistosomiasis is more prevalent (Gad et al. 2011).

Control

Primary healthcare centers played a key role in the implementation of control activities launched by the MOH in 1971. During 1973–1974, seven centers were designated to oversee the control activities. Molluscicide, positive case finding, and treatment were effective in 1979.

During the period from 1990 to 1994, prevalence of *S. mansoni* was greatly reduced (Youssef et al. 1998); in 2003 prevalence had decreased down to 0.007 %. Thereafter, a comprehensive elimination program was launched; accordingly KSA was classified into three regions (1) schistosomiasis free areas, group A, (2) low endemic areas, group B, and (3) high endemic areas, group C. In addition to chemotherapy and molluscicide, provision of potable water, environmental sanitation, and health education were applied (WHO 2007). Saudi Arabia is one of the ideal situations for effective application of snail control because the irrigation network is limited, and transmission foci are well defined (Arfaa 1976; Al-Madani 1990).

According to the annual MOH report, the outcome of the program was very efficacious; infection rates were 2.2, 2.9, and 2.78/100,000 in 2000, 2004, and 2008 respectively. Also, examination of 34,305 water bodies detected infected snails in

778 sites only (Saudi Arabia Ministry of Health 2004). However, the impact of the control program in Asir was not as effective as in other provinces (Fayed 1985).

Asir is situated in the southwestern part of KSA, bordering Yemen in a very limited area. Topography of Asir is an important factor contributing to difficulty in control of schistosomiasis. It consists of three regions: Asir Range comprising the mountainous area, Asir Plateau representing an upland that extends from Asir Range, the drainage of Asir Plateau is unsatisfactory and interrupted which favors flourishing of snail breeding places. The third zone is the coastal plain known as Tihama. The topography of the region helps in disseminating the snails from the high land of Asir Range to lower areas in Asir Plateau and the coastal plain of Tihama. Also, it is difficult to contact Bedouins living in this area due to their constant movements from place to place (Al-Madani 1991).

S. mansoni is mainly prevalent in Asir Range (9.1 %), while *S. haematobium* is prevalent in Asir Plateau and Tihama (7.5 %) (Fayed 1985). However the Annual Health report of the Ministry of Health recorded lower rates for *S. mansoni* (4.6 %) and *S. heamatobium* (2.2 %); still these rates are much higher than other provinces (Al-Madani 1991). Abiotic and biotic factors which might contribute to high transmission in Asir were investigated over an 8-year period (2000–2007). Inaccessibility to health services was one of the contributing factors in addition to hot humid summer climate, topography, and hydrographic changes; these factors influence breeding of snails (Shati 2009).

The contribution of schistosome genetic diversity to high prevalence in Asir needs to be investigated. Several studies in KSA explored genetic variability within the same strain collected from different regions (Shalaby et al. 2011; Mostafa et al. 2012). Genetic diversity might influence the force of infection, pathogenicity, immunogenicity, and the response to chemotherapy (Thiongo et al. 1997).

The role of animal reservoir hosts for *S. mansoni* in KSA should be considered. Infection was detected in Hamadryas baboons, which live in close proximity to humans in areas extending from the Yemen border to the Midwest Region (Nasher 1988; Yamane et al. 2003). Other factors that might hinder the success of control programs are: uncontrolled population movement from the highly endemic neighborhood in Yemen and the creation of multiple irrigation projects. However, schistosomiasis is mainly clustered in poor countries, while Saudi Arabia has a high income economy (one of the strongest in the Gulf region). It is worth mentioning that schistosomiasis has been eradicated from Japan despite widespread animal reservoir hosts contributing to over 80 % of transmission (Wang et al. 2005). Also, irrigation projects can be constructed to hinder breeding places and to limit human access for domestic activities; China is a good example where control of schistosomiasis is being maintained in spite of vast expansion of irrigation projects (Fenwick et al. 2006). It can be concluded that with comprehensive integrated control programs, elimination of schistosomiasis is likely to occur in high income economy.

Fig. 10 Map of Yemen indicating the location of major cities and governorates Copyright: © Alyousefi et al. 2011. This is an open-access article, free of all copyright, and may be freely reproduced, distributed, transmitted, modified, built upon, or otherwise used by anyone for any lawful purpose. The work is made available under the Creative Commons CC0 public domain dedication

Human Schistosomiasis in Yemen

History

Yemen is a developing Middle Eastern country located at the southern part of the Arabian Peninsula with a total population of 25 million. This country depends totally on ground and rain water as a source of water. Recently, the country has fallen into a deep water crisis characterized by very rapid mining of groundwater, extreme water supply shortages in the major cities, and limited access of the population to safe drinking water. WHO reported that only 25 % of the population had easy access to safe water (WHO 2009; Alyousefi et al. 2011).

Being one of the poorest countries in the Middle East, 42 % of Yemen's total population is estimated to be under the national poverty line (World Bank 2004). The poverty ratio is higher in rural areas where 75 % of the population lives and only 25 % is covered with healthcare services compared to 80 % of urban areas (Alyousefi et al. 2011) (Fig. 10).

The economy of the country depends mainly on agriculture, most of the population being involved directly or indirectly in this field. New agricultural projects have been established and many of the previous ones extended, so the irrigation system is extensive (Nagi 2005).

Fig. 11 Artificial water pool of the type that contributes to sustaining transmission of schistosomiasis in the mountainous areas of Western Yemen. ©WHO/R. Ben Ismail

Schistosomiasis is one of the most important public health problems in Yemen (Nagi 2005). The Ministry of Public Health ranks *Schistosoma* infections second to malaria from a socioeconomic point of view and is the sixth major health problem in the country (Ministry of Public Health 1995). Yemen is the second in having the greatest number of schistosomiasis cases in the MENA Region (Hotez et al. 2012).

Epidemiology

Human schistosomiasis (both urinary and intestinal) are endemic in Yemen with three million people infected (Nagi 2000) and 600,000 suffering from clinical morbidity likely to result in death (Oshish et al. 2011; WHO 2012). Every year, around 2,000 people die of schistosomiasis, but this is not the exact figure as there are no reliable statistics in the country (IRIN Middle East 2008).

Transmission occurs in a large proportion of Yemen, with the mountainous areas in the western part of the country appearing to be the most severely affected (WHO 2012) (see Fig. 11).

Schistosomiasis was found to affect populations where substandard conditions of living are predominant, e.g., poor sanitation, insufficient safe water supply, and low standard of hygiene is practiced (Raja'a et al. 2001). Agricultural workers are at high risk of acquiring schistosomiasis infection because of their daily work in the fields and continuing contact with *Schistosoma*-infected water (Nagi 2005). Children who practice swimming are particularly at risk because of their prolonged and complete body exposure (Al-Shamiri et al. 2011), as well as their lower levels of acquired immunity (Woolhouse et al. 1991; Fulford et al. 1992). Children not enrolled in schools are thought to harbor particularly heavy infections (Nagi 2005; Hussein et al. 1996). Moreover, the erroneous habits of people as regards urination and defecation in canal water, bathing, washing utensils and clothes, walking barefoot during irrigation in agriculture, or fishing make them at risk of acquiring the infection (Sibomana 2009) (Fig. 11).

Despite the fact that safe, effective anti-*Schistosoma* treatment is at hand and considerable households have access to a safe water supply (51 %), the rate of *Schistosoma* infection is expected to increase (Raja'a et al. 2001). This is due to the suitable environment created by agricultural expansion linked with increased dam construction as a result of the water policy applied during the last decade of the millennium; combined, these changes have generated an optimal environment for both freshwater snails *Bi. arabica* and *Bu. truncatus*, which are the intermediate hosts for *S. mansoni* and *S. haematobium*, respectively (Steinmann et al. 2006). These snails were found to be highly susceptible to infection with local Yemeni strains of *S. mansoni* and *S. haematobium* under laboratory conditions (Nagi et al. 1999). Moreover, there is insufficiency, including inadequate household coverage with a safe water supply and lack of public health services, a high rate of illiteracy (50 %), and a lack of an indoor latrine in a considerable proportion of houses (37 %). Nevertheless, a comprehensive control policy is not effectively implemented due to costly requirements (Raja'a et al. 2001).

Schistosoma infection results in reduced school attendance via its major sequelae of anemia, growth stunting, and cognitive impairment (Engels et al. 2002) and is significantly associated with chronic abdominal pain, diarrhea, and malnutrition (King et al. 2005). The longer-term serious disease complications are organomegaly, particularly the liver and spleen, intestinal schistosomiasis, bladder cancer, and damage to the female genital tract from urinary schistosomiasis (Poggensee and Feldmeier 2001; King and Dangerfield-Cha 2008).

The distribution of *Schistosoma* infections across the country was a matter of research in several published papers. *Schistosoma* infections were reported from areas such as Sana'a and Saada (Yemen *Bilharzias* Control Project 1993), Marib (Nagi and Molan 1992), Taiz (Hazza et al. 1983), Ibb (Al-Haddad and Assabri 1998; Raja'a et al. 2000), Hajja (Azazy and Al-Dullaimi 1999), central highlands (Schaap et al. 1992), Aden and Yahr (Zain 1998).

Nagi et al. 1999 conducted an epidemiological survey during 1992. A total of 2,902 students of 13 schools in Sana'a Governorate, 800 students of three schools in Saada Governorate, and 2802 students of 14 schools in Hajja Governorate were included. The infectivity rate of *S. mansoni* was (7.6 %–18.8 %–76.3 %) and of *S. haematobium* was (52.2 %–10.1 %–49.0 %) in Hajja–Sana'a and Saada respectively. Males had a higher infection rate than females and *S. mansoni* was more prevalent than *S. haematobium*, which is similar to the findings of Hazza et al. (1983) and Farag (1985). Bloody stools were found in 61.7 % of *S. mansoni* cases and abdominal pain and/or diarrhea in 50 %. Heamaturia was seen in 62.5 % of *S. haematobium* cases while painful micturition in 33.3 %. Such findings have often been reported (Gilles 1982; Warren 1984).

Raja'a et al. (2000) conducted an epidemiological comparative survey aimed at determination of prevalence and focal distribution of *Schistosoma* infection and intestinal parasites to provide a reference for evaluating the need for community intervention. A total number of 230 children (5–18 years) from 7 villages that lie on the Assahul Valley of Ibb Governorate in Yemen were included. The *Schistosoma* infection rate was 37 % (S. *mansoni* 35 % and *S. haematobium* 5 %). Significant

associations were found between *Schistosoma* infections with residence near the valley, male gender, and frequent water contact activities. The detected rates of infection (37 %) exceeded the estimations reported for the whole country (6 %) (Farag 1985), Mahweet (27 %) (Raja'a et al. 2001), and Hajja (21 %) (Azazy and Al-Dullaimi 1999). Exceedingly high rates (37 % for *S. haematobium* and 64 % for *S. mansoni*) were reported from Taiz (Hazza et al. 1983).

In year 2003, 515 school children from five schools in Abyan and Taiz Governorates in Yemen were screened by Ahmed (2009) for microhematuria using reagent strip method and for the presence of *S. haematobium* ova by filtration method as well as carrying out a questionnaire for hematuria. The prevalence of the infection as determined by filtration, questionnaire, and reagent strip method was 21.4 %, 22.2 % and 30.9 % respectively. The author concluded that the reagent strip method is practical, cheap, fast, and easy to perform in primary healthcare setting and method for screening and monitoring *S. haematobium* infection. Its performance can be enhanced when used in combination with questionnaire without additional costs.

Al-Shamiri et al. (2011) examined 1,406 stool samples and 1,484 urine samples of school children (5–16 years) from 32 basic schools in five districts in five schistosomiasis endemic areas (Al-Dhabab, Hedran, Warazan, Al-Barhand, Al-Shmaytin) during the period from June 2007 to March 2009. The overall prevalence was 20.8 % for *S. mansoni* and 7.4 % for *S. haematobium*. *S. mansoni* was more prevalent than *S. haematobium*, which was attributed to the distribution of *Biomphalaria* snails which is more abundant than that of *Bulinu*s snails. Riadh Ben-Ismail, WHO's regional adviser (IRIN Middle East 2008), mentioned that intestinal schistosomiasis differs from that of the urinary variety; it might not fully respond to the drugs. Moreover, some animals (e.g., monkeys) carry intestinal schistosomiasis and can transmit it back to humans.

Control

Intestinal parasitic infections had received attention in Yemen as early as 1950s; most of these efforts were to combat schistosomiasis (Kuntz et al. 1953; Hazza et al. 1983). Preventive chemotherapy with the safe, effective, and cheap drug PZQ is the cornerstone of the WHO recommended approach against schistosomiasis, which aims to keep parasite numbers suppressed in order to avoid clinical manifestations of infection (Oshish et al. 2011). Many schistosomiasis control programs have distributed drugs using a school-based platform to reduce infection levels and related morbidity (Fenwick et al. 2009). This approach has considerable logistical and epidemiological advantages such as the ability to build on the school infrastructure in order to ensure high treatment coverage, the use of teachers to administer drugs and record compliance, and the fact that school-age children typically harbor the heaviest burden of infection, as well as subsequently making the greatest contribution to transmission (Ritcher 2003). Children are also easy to approach with a health education program, and they are easy to reach physically for

chemotherapy. Moreover, children represent the future of developing countries (Nagi 2005). It has been postulated that by treating children at least three times during their school-age years, severe morbidity can be avoided in later life (Ritcher 2003).

Raja'a et al. 2001 studied the prevalence, intensity, and incidence of schistosomiasis among school children in a previously ignored area (Al Mahweet) in Yemen. A total of 897 pupils aged 5–18 years (453 from Al Mahweet town and 444 from rural surrounding areas) participated in the study. It was found that annual intervention with chemotherapy only, neglecting the other components of the comprehensive control program, is satisfactory decreasing the infection rate of *S. mansoni* by 62.5 %. However, the authors recommended that the time interval for retreatment of cases with *S. haematobium* should be shortened or combined with the other control measures. They also recommended mass treatment for boys of rural Al-Mahweet who visit the water source at least once per week.

Nagi (2005) conducted an intervention study targeting the community and school children in Khamir, located 90 km north of Sana'a for controlling schistosomiasis using chemotherapy and health education. Community and school baseline survey included 913 individuals of 100 houses and 323 children randomly selected from 14 schools in Khamir. The prevalence of *S. haematobium* infection 14 months post-intervention fell from 58.9 % to 5.8 % and the frequency of heavy infection from 40 % to 18.9 %. Health education sessions resulted in significant decrease in the frequency of contact with water sources and greater adherence to preventive measures. The author concluded that an integrated community and school-based program combining chemotherapy and health education can be effective for control of *S. haematobium* in endemic areas.

Subnational control has been ongoing since 2006 in Yemen via the distribution of PZQ against schistosomiasis and albendazole (ALB) against soil-transmitted helminthes using school-based treatment. In 2008, the Yemen National Schistosomiasis Control Program (NSCP)—the first of its kind in Yemen—was instigated with the aim of controlling schistosomiasis nationwide (Oshish et al. 2011).

With support from a separate World Bank grant, the NSCP utilized a school-based distribution system to treat school-age children (6–18 years) reaching enrolled and non-enrolled children in those areas with the highest endemicity of schistosomiasis across the country. The campaign was implemented in four phases during 2008 (first from 10 to 14 March, second 24 to 27 March, third 5 to 8 April, and the fourth phase 18 to 21 October) targeting 2,583,309 children from 5,495 schools in 107 districts in 14 provinces (69 % at primary schools and 31 % non-enrolled). PZQ and ALB were administered by 4,426 trained teachers and 3,034 health workers (IRIN Middle East 2008). This resulted in a very high coverage for enrolled school children (94 %) but a lower figure for non-enrolled school-age children (68 %) (Oshish et al. 2011).

To improve this and to expand treatment to adults in high and medium infected areas, a pilot program ran from 27 to 30 December 2009 in 10 high endemicity districts in the three governorates of Sana'a, Dhamar, and Hajjah using a combination of PZQ (against schistosomiasis; 40 mg/kg administered using a dose pole) and

ALB (against soil-transmitted helminthes; a single 400 mg tab/person). It was based on two complementary treatment approaches, campaign-based preventive chemotherapy and routine preventive chemotherapy. The campaign-based preventive chemotherapy constituted the active phase of the campaign. PZQ and ALB were distributed using fixed (schools and health facilities) and temporary sites (mobile teams). In 2009 the school-based teams did not treat non-enrolled children as this approach in 2008 yielded disappointing results. The treatment target was 300 persons/day per team for a period of 4–5 days. Health facilities were implemented at the same time as the neighboring schools in order to reach adults and non-enrolled school-age children. Leaflets—radio messages—announcements via public address systems attached to the vehicles of the village leaders and distribution teams were used to attract participants. Treatment target was 300 persons/day/team (Oshish et al 2011)

Temporary sites such as community leader houses, mosques, market places were used by mobile teams in order to reach as many of target population as possible; in most areas 300 persons per day per team was the target. Routine preventive chemotherapy was developed whereby sufficient drugs were retained within the routine health system of the Ministry of Public Health and Population (MOPHP) (health facilities, hospitals, dispensaries) in order to passively treat cases among individuals not targeted by the campaign-based preventive chemotherapy, those who missed treatment, or those who suffered reinfection. Health education and social mobilization were identified as important in ensuring community acceptance, high treatment coverage, and therefore success of the control program. The new approach achieved coverage of 90.1 % of non-enrolled children: a 40 % increase compared with the same districts in 2008, and coverage of 97.9 % of enrolled children, a 2 % increase compared to 2008. Coverage of females was 81.8 % and of adults in general was 73.9 % (Oshish et al. 2011).

The result of this pilot program was helpful informing the design and direction of the national program (2010–2015). The NSP aims to eliminate schistosomiasis-related morbidity in Yemen via repeated periodic chemotherapeutic treatment with PZQ (40 mg/kg) to all those who require it (Table 4), and the dissemination of relevant health education messages, over the 6-year life span of the program. This is supplemented with treatment with ALB to treat common soil-transmitted helminthiasis (Oshish et al. 2011).

The first nationwide control occurred in the operational year 2010 (July 2010–May 2011) with ambitious plans to treat approximately 10 million people across the country over three campaigns (Oshish 2011). The annual anti-*Schistosoma* campaign was launched on 10 March 2013, the first phase of the second operational year, 2012–2013. It will cover 160 districts in 12 governorates and target about 45 % of Yemen's 24 million population aged 6 years and older. This will be followed up with a second phase of the campaign that will target two million people in the remaining nine endemic governorates in mid-April 2013 (Weldon 2013)

Table 4 Treatment approach in areas of variable endemicity for the main treatment campaigns

Area	Criteria[a]	School-based treatment	Community-based treatment
High prevalence area	>40 % of either infection	Years 1, 2, 3, 4, 5, 6	1, 2, 4
Medium prevalence area	10–40 % of either infection	Years 1, 2, 4, 6	Year 1
Low prevalence area	<10 % of either infection	Years 2, 5	ND
Suspect area	Currently unmapped areas	Years 1, 2, 4, 6	Year 1

The districts (of which there are 333 in Yemen) is the unit of implementation
ND not done
[a]These cutoff points do not coincide with the WHO recommendations of >50 %, 10–50 %, and <10 % respectively (Steinmann et al. 2006);they have been altered in order to expand treatment to more needy people and to further decrease prevalence and intensity of infection. Year 1–6 refers to 2010–2015 respectively. Reproduced, with the permission of the publisher, from Oshish et al. (2011)

Yemen is the only country in the Middle East not to have eliminated the disease (IRIN Middle East 2008). The significant World Bank funds—being allocated to the 6-year control program in Yemen—will continue provided the political situation there returns to a level that allows drug distribution (Hotez et al. 2012)

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