

## **REVIEW**

# **Soil transmitted helminth infections and schistosomiasis in school age children in sub-Saharan Africa: Efficacy of chemotherapeutic intervention since World Health Assembly Resolution 2001**

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**Abstract:** Soil transmitted helminth infections (STH) and schistosomiasis constitute major public health challenges among school-age children in sub-Saharan Africa. This review assessed the efficacy of chemotherapeutic intervention in line with the World Health Assembly (WHA) resolution since the passage in 2001. Using the Medline Entrez-Pubmed search, relevant publications were identified via combinations of key words such as *helminth infection*, *school children*, *chemotherapy*, *Africa*. Albendazole, mebendazole, and praziquantel were the antihelminthic drugs most commonly evaluated. Cure rates >80% and egg reduction rates >90% were recorded in most cases of schistosomiasis using praziquantel. Albendazole was very effective against *A. lumbricoides* and hookworm infections with majority of the studies recording cure rates >75%, but the efficacy of the drug was poor against *T. trichiura*. To ensure the realization of the WHA resolution, there is need for regular treatment of school children, development of alternative antihelminthic drugs and vaccines, environmental control measures and health education.

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**Key words:** soil transmitted helminth, schistosomiasis, infection, children, chemotherapy, Africa

## **Introduction**

In the vast majority of developing tropical and subtropical regions of the world, helminth infections particularly those caused by soil transmitted helminths (STHs) and schistosomes constitute major public health and developmental challenges. Infections caused by STHs – including hookworm (*Necator americanus*, *Ancylostoma duodenale*), roundworm (*Ascaris lumbricoides*), whipworm (*Trichuris trichiura*) and schistosomes (*Schistosoma haematobium*, *Schistosoma mansoni*) are associated with poverty and underdevelopment and are most prevalent in the poorest communities of the developing world including almost all countries of the sub-Saharan Africa (Montresor *et al.*, 1998; WHO, 2002). The burden of these helminth infections has been consistently underestimated in the past, but there is now a general consensus that STH infections and schistosomiasis represent an important public health problem especially for children (Keiser *et al.*, 2002; WHO, 2002; Tchuente *et al.*, 2003; Bethony *et al.*, 2006).

Current estimates indicate that an estimated 4.5 billion individuals are at risk of STH infections and the global estimate of number of cases of *A. lumbricoides* is 807 million, *T. trichiura* 604 million, Hookworm (*N. americanus*; *A. duodenale*) 576 million, Schistosomiasis (*S. haematobium*, *S. mansoni* and *S. japonicum*) 207 million (Bethony *et al.*, 2006; Hotez *et al.*, 2008). Although estimates of disability-adjusted life years (DALYs) lost due to these helminth infections portray a more accurate picture of the disease burden caused by the infections, the estimates of DALYs lost differ greatly from one source to another (WHO, 2002; Van der Werf *et al.*, 2003; King *et al.*, 2005; DCCP, 2008). In the current Global Burden of Disease (GBD) assessments by the WHO for instance, it is not clear whether prevalence of infection *per se* was used to gauge the disease burden of helminths or the more appropriate duration of infection-associated pathology, which is

often irreversible (Hotez *et al.*, 2008). However, total DALYs lost annually may range from 4.7 million to 39 million (DCPP, 2008).

Because STHs are transmitted through poor sanitation and hygiene, and schistosomiasis by contact with infected freshwater streams and lakes, school-aged children are typically at increased risk resulting in high prevalence and intensity of infection due to high level of exposure (Montresor *et al.*, 1998; WHO, 2002). Although light helminthic infections are often asymptomatic, the adverse health and nutritional impacts of severe worm infections on children are well documented: helminthic infections often lead to iron deficiency anaemia, protein energy malnutrition, stunting (a measure of chronic undernutrition), wasting (a measure of acute undernutrition), listlessness and abdominal pain (Van der Werf *et al.*, 2003; King *et al.*, 2005; Bethony *et al.*, 2006), and may negatively affect class-attentiveness of schoolchildren (Berhe *et al.*, 2009). Without chemotherapeutic treatment, the infections may also have more serious medical consequences in a minority of cases: roundworm infections sometimes lead to fatal intestinal obstruction, hookworm infection can cause severe anaemia, whipworm is associated with chronic dysentery, and urinary schistosomiasis can result to severe damage of the kidneys and/or bladder, while *S. mansoni* infection can cause lesions of the liver, portal vein, and spleen, leading to periportal fibrosis, portal hypertension, hepatosplenomegaly, splenomegaly, and ascites (Bundy, 1995).

The availability of safe and relatively inexpensive drugs for both schistosomiasis (praziquantel) and STHs (albendazole and mebendazole) has made control through chemotherapy a potentially affordable option even in resource-poor countries (Handzel *et al.*, 2003). Consequently in May 2001, the World Health Assembly (WHA) recognized that where control measures including chemotherapeutic interventions have been implemented in a sustainable way, as demonstrated in several countries, mortality, morbidity and transmission have decreased dramatically (WHA, 2001). Therefore the WHA passed resolution 54.19 endorsing regular treatment of high-risk groups, particularly school age children, as the best means of reducing morbidity and mortality (WHA, 2001). The WHA therefore recommended that Member States should 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; with the goal of attaining a minimum target of regular administration of chemotherapy to at least 75% and up to 100% of all school-age children at risk of morbidity by 2010 (WHA, 2001). Implementation of this recommendation was facilitated by the establishment of the Partners for Parasite Control (PPC; <http://www.who.int/wormcontrol>), and the Schistosomiasis Control Initiative (SCI; <http://www.sci-ntds.org/>) (Fenwick, 2006; Kabatereine *et al.*, 2006).

The overriding objective of this report therefore was to assess the efficacy of chemotherapeutic interventions for STH infection and schistosomiasis among school children in sub-Saharan Africa in line with the WHA resolution since the passage in 2001. This is with the view to highlighting the need for operational research on the use of chemotherapy, the development of pragmatic public health policy on the prevention, support activities and prompt treatment, in light of the epidemiological importance of soil transmitted helminth infections and schistosomiasis and their effects on child well-being in sub-Saharan Africa.

## Materials and Methods

A MEDLINE Entrez-Pubmed search was performed and studies conducted in sub-Saharan Africa on the use of chemotherapeutic interventions to address soil transmitted helminth infection and schistosomiasis in school age children were identified. Combinations of key words such as *helminth infection, school children, chemotherapy, Africa*, were used for the search which yielded 212 entries as of November 2009. Entries published between 2001 and 2009 which totalled 81 were considered and those which focused on the outcome of chemotherapeutic intervention against soil transmitted helminth infection and/or schistosomiasis in school age children most relevant to the objective of the review were identified. Bibliographies of all papers obtained were checked for additional relevant references and were obtained and included in the review. Particular attention was paid to articles providing information on the pre-chemotherapeutic treatment and post-chemotherapeutic treatment prevalence of soil transmitted helminth infection and schistosomiasis in school age children. The various reports were systematically reviewed with respect to the location, population, the period, type of study and outcome of study to enhance comparison between studies.

## Results

A total of twenty-eight studies fulfilled the criteria for this study and were categorized into two. The first category consisted of studies which investigated the efficacy of the schistosomicidal drugs for mass chemotherapy among school children in sub-Saharan Africa (Table 1). The second category was made up of studies which provided information on the outcome of mass chemotherapy using antihelminthic drugs for STHs among sub-Saharan African school children (Table 2).

### *Efficacy of mass chemotherapeutic interventions on schistosome infections in school children*

Up to sixteen studies were identified which investigated the efficacy of various schistosomicidal drugs used for mass chemotherapy among school children. The drugs assessed were praziquantel (PZQ), artesunate (ART), oxaminiquine (OXA), amodiaquine (AMQ) and sulphadoxine-pyrimethamine (SP) (Table 1). Generally there were significant reductions in the prevalence of schistosomiasis among school children following the chemotherapeutic interventions as well as significant increase in cure rates and egg reduction rates. Most of the studies used PZQ and cure rates >80% and egg reduction rates >90% were recorded in most cases, however low cure rates of 33% (N'Goran *et al.*, 2001) and 41% (Tchuenta *et al.*, 2004) were also observed. Other schistosomicidal drugs such as ART and OXA produced cure rates >70% in Nigeria (Inyang-Etoh *et al.*, 2004) and Kenya (Thiong'o *et al.*, 2002) respectively. It was demonstrated in two studies that drug combinations such as PZQ+ART, SP+ART, AMQ+ART produced higher cure rates than when one drug type was used (Inyang-Etoh *et al.* 2008; Boulanger *et al.*, 2007) (Table 1). Cure rates for *S. mansoni* ranged from 57.8% in Uganda (Kabatereine *et al.*, 2007) to 100% in South Africa (Jinabhai *et al.*, 2001), while cure rates for *S. haematobium* ranged from 33.0% in Cote d'Ivoire (N'Goran *et al.*, 2001) to 94.5% in Senegal (Boulanger *et al.*, 2007).

**Table 1: Summary of chemotherapeutic interventions studies on the impact of schistosomicidal drugs on schistosomiasis among schoolchildren in Sub-Saharan Africa**

Country	Type of Study	Species	Drug used	Pre/post treatment prevalence (%)	Cure rate (%)	Egg reduction rate (%)	Post-treatment assessment time	Reference
Nigeria	CI	<i>S. haematobium</i>	PZQ	NA	72.7	NA	8 weeks	Inyang-Etoh et al., 2009
Nigeria		<i>S. haematobium</i>	ART	NA	70.5	NA	8 weeks	
		<i>S. haematobium</i>	PZQ+ART	NA	88.6	NA	8 weeks	
	CI	<i>S. haematobium</i>	ART	NA	70.1	NA	4 weeks	Inyang-Etoh et al., 2004
Zimbabwe	CI	<i>S. haematobium</i>	PZQ	NA	88.5	98.2	6 weeks	Midzi et al., 2008
Burkina Faso	CI	<i>S. haematobium</i>	PZQ	59.6/7.7	87.0	92.8	2 years	Touré et al., 2008
Senegal	RCT	<i>S. haematobium</i>	SP+ART	NA	92.6	NA	4 weeks	Boulanger et al., 2007
		<i>S. haematobium</i>	ADQ+ART	NA	68.7	NA	4 weeks	
Kenya	CI	<i>S. mansoni</i>	PZQ	47.4/8.6	81.9	NA	8 weeks	Kihara et al., 2007
Kenya	PC	<i>S. haematobium</i>	PZQ	67.0/21.0	94.5	NA	12 months	Satayathum et al., 2006
Kenya	CI/CS	<i>S. mansoni</i> (Kangundo)	PZQ	NA	77.6-87.2	NA	5 weeks	Thiong'o et al., 2002
		<i>S. mansoni</i> (Kibwezi)	PZQ	NA	67.1-81.1	NA	5 weeks	
		<i>S. mansoni</i> (Kangundo)	OXA	NA	71.6-79.7	NA	5 weeks	
		<i>S. mansoni</i> (Kibwezi)	OXA	NA	56.7-87.2	NA	5 weeks	
Cameroon	CI	<i>S. haematobium</i>	PZQ	NA	41.0	90.4	3 weeks	Tchunte et al., 2004
Uganda	CI	<i>S. mansoni</i>	PZQ	42.4/17.9	80.7	83.0	2 years	Kabateriene et al., 2004
South Africa	CI	<i>S. haematobium</i>	PZQ	68.0/13.2	57.8	97.9	12 months	Saathoff et al., 2004a
	CI	<i>S. haematobium</i>	PZQ	22.3/3.3	85.2	NA	16 weeks	Jinabhai et al., 2001
	CI	<i>S. mansoni</i>	PZQ	0.8/0.0	100	NA	16 weeks	
	RCT	<i>S. haematobium</i>	PZQ	43.4/8.3	80.9	NA	12 months	Taylor et al., 2001
Ethiopia	CI	<i>S. mansoni</i>	PZQ	NA	94.0	97.0	NA	Degu et al., 2002
Cote D'Ivoire	CI	<i>S. haematobium</i> (Taabo)	PZQ	94.0/63.0	33.0	87.7	6 months	N'Goran et al., 2001
		<i>S. haematobium</i> (Bodo)	PZQ	90.0/14.0	84.4	91.5	6 months	
		<i>S. haematobium</i> (Batera)	PZQ	88.0/49.0	43.3	62.4	6 months	
		<i>S. haematobium</i> (Assinze)	PZQ	67.0/10.0	85.1	77.8	6 months	
Tanzania	CS	<i>S. haematobium</i>	PZQ	59.0/4.0	94.0	99.0	6 weeks	Guyatt et al., 2001

CI=Chemotherapeutic intervention; PC=Prospective cohort; RCT=Randomized controlled trial; CS=Cross sectional; PZQ=Praziquantel; ART=Artesunate; OXA=Oxamniquine; SP=sulphadoxine-pyremethamine; ADQ=Amodiaquine; NA= not accessible/not determined.

**Table 2: Summary of chemotherapeutic interventions studies investigated the impact of schistosomicidal drugs on schistosomiasis among schoolchildren in Sub-Saharan Africa**

Country	Type of study	Drug	<i>A. lumbricoides</i>			<i>T. trichiura</i>			Hookworm			Post-treatment assessment	Reference
			P/P (%)	CR (%)	ERR (%)	P/P (%)	CR (%)	ERR (%)	P/P (%)	CR (%)	ERR (%)		
Tanzania	CI	ALB	0.9/0.7	22.2	NA	4.8/0.7	85.4	NA	45.6/11.9	73.9	NA	8 months	Massa et al., 2009
Tanzania	RCT	MEB	59.7/3.0	96.5	99.0	90.7/75.0	22.9	81.0	94.9/91.5	7.6	52.1	3 weeks	Albonico et al., 2003
		LEV	59.5/5.7	91.2	98.5	93.8/90.0	9.6	41.5	96.2/87.6	11.9	61.3	3 weeks	
		MEB+LEV	62.0/1.4	98.5	99.1	93.1/74.5	22.9	85.0	94.0/71.8	26.1	88.7	3 weeks	
Tanzania	RCT	PY-OX	NA	>96.0	>95.0	NA	31.5	>80.0	NA	NA	67.0	4 weeks	Albonico et al., 2002
		MEB	NA	>96.0	>95.0	NA	23.3	>80.0	NA	NA	68.0	4 weeks	
Tanzania	CI	ALB	NA	NA	NA	NA	NA	NA	61.0/11.0	82.0	97.6	6 weeks	Guyatt et al., 2001
Ethiopia	CI	MEB	NA	90.6	96.7	NA	NA	NA	NA	83.5	94.2	NA	Adugna et al., 2007
		ALB	NA	83.9	96.3	NA	NA	NA	NA	84.2	95.0	NA	
Kenya	CI	ALB	1.6/0.0	100	NA	0.8/0.6	25.0	NA	16.7/ 0.2	98.8	NA	8 weeks	Kihara et al., 2007
Kenya	CI	ALB	NA	83.5	NA	NA	67.8	NA	NA	92.4	96.7	6 months	Muchiri et al., 2001
		MEB	NA	79.6	NA	NA	60.6	NA	NA	50.0	66.3	6 months	
Uganda	CI	ALB	2.8/0.6	78.6	NA	2.2/1.6	27.3	NA	50.9/10.7	79.0	92.9	2 years	Kabateriene et al., 2007
South Africa	CI	ALB	NA	NA	NA	NA	23.0	96.8	NA	NA	NA	NA	Adams et al., 2004
South Africa	CI	ALB	22.0/0.8	96.4	97.7	59.8/52.2	12.7	24.8	82.9/17.6	78.8	93.2	3 weeks	Saathoff et al., 2004
South Africa	CI	ALB	29.5/4.7	84.1	NA	51.9/38.0	26.8	NA	3.1/0.0	100	NA	16 weeks	Jinabhai et al., 2001
South Africa	CI	ALB	58.9/17.4	68.9	NA	83.6/61.5	26.4	NA	59.4/0.0	100	NA	12 months	Taylor et al., 2001

CI=Chemotherapeutic intervention; RCT=Randomized controlled trial; MEB=Mebendazole; ALB=Albendazole; LEV=Levamisole; PY-OX=Pyrantel oxantel; P/P= Pre/post treatment prevalence; CR= Cure rate; ERR= Egg reduction rate; NA= not accessible/not determined

### *Efficacy of mass chemotherapeutic interventions on STH infections in school children*

There were twelve studies under this category which investigated the efficacy of mass chemotherapeutic interventions on STH infections using the following drugs: albendazole (ALB), mebendazole (MEB), levamisole (LEV), pyrantel-oxantel (PY-OX). There were significant reductions in the prevalence of STH infections among the school children following the chemotherapeutic intervention (Table 2). Although cure rates were not always high, all the drugs however produced significant increase in egg reduction rates. ALB was very effective against *A. lumbricoides* and hookworm infections with majority of the studies recording cure rates >75%, but the efficacy of the drug was poor against *T. trichiura* with many of the studies recording cure rates <27% (Table 2). Other drugs used (MEB, LEV, PY-OX) also recorded poor efficacy against *T. trichiura*. Albonico et al. (2003) however observed higher cure rates and higher egg reduction rates when MEB and LEV were combined than when each drug was used separately.

### **Discussion**

The findings of this report clearly indicate that in the absence of mass chemotherapy the prevalence of STH infections and schistosomiasis among school children in sub-Saharan Africa remains high. This situation is worrisome because despite the increased awareness created and concern expressed by the WHA in 2001 that 2000 million people are infected by schistosomes and soil-transmitted helminths worldwide, of whom 300 million have associated severe morbidity (WHA 2001), the prevalence of these helminth infections remains very high even after the year 2001 when the WHA endorsed mass chemotherapeutic intervention. Although STH infections and schistosomiasis rarely cause fatality, chronic infection with high worm burden can lead to serious health consequences including malnutrition, physical and intellectual growth retardation, and cognitive and educational deficits in school-age children (King *et al.*, 2005; Van der Werf *et al.*, 2003). The need for sub-Saharan African countries to embark on a pragmatic approach to mass chemotherapy against STH and schistosomiasis cannot be overstated.

Furthermore evidence has emerged suggesting that STH infections and schistosomiasis exacerbate the transmission and/or severity of HIV/AIDS, malaria and tuberculosis and infected individuals may fail to develop protective immune responses when exposed to pathogens, such as *Plasmodium* (causing malaria), *Mycobacterium* (causing tuberculosis) and HIV (causing AIDS) (Druilhe *et al.*, 2005; Borkow & Bentwich, 2006; Elias *et al.*, 2006; Fincham *et al.*, 2003; Kjetland *et al.*, 2006). These findings highlight the fact that the public health implications of STH infection are much greater than previously realized and that STH infection may indirectly contribute to significant mortality worldwide (DCPP, 2008). However in spite of the public-health importance of STH infections and schistosomiasis, they remain neglected by the medical and international community largely because, these diseases are particularly rampant in developing countries and inflict a disproportionate burden on the global poor; second, the infections cause chronic ill health and have insidious clinical presentation; and third, quantification of the effect of soil-transmitted helminth infections on economic development and education is difficult (Bethony *et al.*, 2006; Lammie *et al.*, 2007; Hotez *et al.*, 2007).

The high prevalence and high infection intensity prior to chemotherapeutic intervention recorded in the studies reviewed in this report necessitates regular treatment of schoolchildren in sub-Saharan Africa according to World Health Organization (WHO)

criteria (WHO, 2002), and justify the resolution made by the WHA (2001). It is pertinent to state however, that since the adoption of the WHA resolution, great progress has been made in a number of sub-Saharan African countries in the control of STH infections and schistosomiasis via mass chemotherapy among school children (Jinabhai *et al.*, 2001; Adams *et al.*, 2004; Mafe *et al.*, 2005; King, 2006; Kihara *et al.*, 2007; Adugna *et al.*, 2007; Midzi *et al.*, 2008). In many parts of sub-Saharan Africa there is currently a growing awareness of the public health significance of these helminth infections which previously were grossly neglected, and concerted advocacy for their control has resulted in increased political will and financial means to combat them (Keiser & Utzinger, 2008). It is however unclear whether existing financial resources and global political commitments are sufficient to reach the World Health Assembly's ambitious goals in the sub-region and other developing parts of the world (Hotez *et al.*, 2007). The obstacles to achieving this are substantial and depend in large part on whether countries have reliable and sustainable systems for delivering deworming drugs and addressing other challenges associated with the large scale use of antihelminthic drugs.

The WHA had in 2001 endorsed the regular treatment of high-risk groups, particularly school age children with single-dose drugs against schistosomiasis and soil-transmitted helminth infections. Consequently, four antihelminthics that are currently on the WHO model list of essential medicines for the treatment and control of STH include albendazole, mebendazole, levamisole, and pyrantel pamoate (WHO, 2002, 2006a), while chemotherapy with praziquantel is the mainstay for the treatment and control of schistosomiasis (WHO, 2006a; Colley *et al.*, 2001). Each of these drugs has an excellent safety record; adverse reactions are minimal and transient, and serious adverse experiences are extremely infrequent (WHO, 2006a).

Although the four single-dose drugs endorsed for use in the treatment of STH infection are available, in practice, however, most interventional studies reviewed in this report used only the benzimidazoles (albendazole and mebendazole) because of the added advantage that they are given as a single-dose tablet and children do not need to be weighed (Albonico *et al.*, 2003). Furthermore, the findings of this review indicated that benzimidazoles exhibited considerable cure rates and egg reduction rates particularly against *A. lumbricoides* and hookworms (Guyatt *et al.*, 2001; Jinabhai *et al.*, 2001; Saathoff *et al.*, 2004b; Adugna *et al.*, 2007; Kihara *et al.*, 2007;) and aside from reducing the load of worms, benzimidazole treatment has been shown to improve the nutritional status and cognitive development of children infected with *A. lumbricoides*, *T. trichiura*, and hookworms and reduces hookworm associated anaemia in children (Albonico *et al.*, 1996; Stoltzfus *et al.*, 1998). On the other hand studies reviewed indicated that a single oral dose of 40 mg of praziquantel per kg of body weight was safe, showed no or only a few but transient side effects, but resulted in high parasitological cure and egg reduction rates against both *S. mansoni* and *S. haematobium* (Berhe *et al.*, 1999; Taylor *et al.*, 2001; Guyatt *et al.*, 2001; Degu *et al.*, 2002; Saathoff *et al.*, 2004a; Midzi *et al.*, 2008).

Interestingly, a randomized comparison of low-dose (20mg/kg) with standard dose (40 mg/kg) praziquantel therapy suggests an equivalent effect of these two regimens in reducing structural urinary tract morbidity over a nine-month period and concluded that in certain settings, a 20 mg/kg dose of praziquantel may be sufficient in providing practical control of renal and bladder morbidity due to *S. haematobium* infection (King *et al.*, 2002). Further studies are however required to validate this finding in other areas of sub-Saharan Africa. Nevertheless, the WHO height dose pole for 40mg/kg standard doses makes it

considerably easier to effectively distribute the praziquantel tablets in resource poor settings (WHO, 2002).

In view of the operational and therapeutic properties as well as the gradually decreasing costs of praziquantel, millions of people have been treated with praziquantel over the past 20 years and it is predicted that many more millions of individuals suffering from schistosomiasis especially school children will be treated with this drug several years to come (Cioli 2000; Doenhoff et al., 2000; Colley *et al.*, 2001).

It is important to state that these antihelminthic drugs have witnessed large scale administration in sub-Saharan Africa and other parts of the world where STH infections and schistosomiasis constitute a public health concern, which is in line with the resolution of the WHA (2001). However, the fact that STH infection and schistosomiasis do not confer protective immunity even after repeated infections and that people treated with the drugs especially children soon become re-infected implies that there will continue to always be a need for drug treatment in control programs. In view of this, there is therefore considerable concern that repeated use of these few drugs over a long period of time might result in the development and spread of drug resistant helminths, which is already a significant problem in veterinary medicine (Keiser & Utzinger, 2008).

In fact, some of the studies reviewed in this report which investigated the efficacy of albendazole, mebendazole and levamisole showed a parasitological cure rates lower than 30% particularly with *T. trichiura* infection (Jinabhai *et al.*, 2001; Taylor *et al.*, 2001; Albonico *et al.*, 2003; Saathoff *et al.*, 2004b; Kihara *et al.*, 2007; Kabatereine *et al.*, 2007; Olsen *et al.*, 2009; Appleton *et al.*, 2009). Although there is limited evidence from the studies reviewed of a possible emergence of drug resistance, this may not be completely overruled. A number of previous studies have indicated that there are no drugs available that are highly effective against *T. trichiura* infection as single dose treatments, but other studies show that two or three repeated doses of albendazole on consecutive days are more effective than a single dose (Horton 2000; Taylor *et al.*, 2001; Jinabhai *et al.*, 2001). To repeat the dose on 2 or 3 days would however increase cost, and might reduce compliance and complicate management (Adams *et al.*, 2004). As a result of this, the need for alternative STH antihelminthics cannot be overstated. Albonico *et al.* (2002) reported that Pyrantel-oxantel (10 mg/kg) offers a valuable alternative to mebendazole as a single-dose treatment for the control of intestinal nematode infections in children in endemic areas of sub-Saharan Africa, due to its comparable efficacy, its low cost and its suitability for use in young children.

Although praziquantel was efficacious against both *S. mansoni* and *S. haematobium* infections with little or no evidence of possible resistance as indicated in this report (Guyatt *et al.*, 2001; Degu *et al.*, 2002; Saathoff *et al.*, 2004a; Midgzi *et al.*, 2008;), other antischistosomal drugs investigated such as oxamniquine, and antimalarial drugs eg. artesunate, amodiaquine and sulphadoxine-pyremethamine were also reasonably effective (Thiong'o *et al.*, 2002; Inyang-Etoh, 2004; Boulanger *et al.*, 2007; Inyang-Etoh *et al.*, 2009). Oxamniquine is the only main alternative antischistosomal drug, but its use is declining (Cioli *et al.*, 2000) and moreover in contrast to praziquantel, which displays activity against all human schistosome species, the activity of oxamniquine is confined to *S. mansoni* (Utzinger *et al.*, 2003). The antimalarial drugs particularly the derivatives of artemisinin (e.g., artemether and artesunate), have been shown to be schistosomicidal and have exhibited high parasitological cure rates. Consequently discussions are on-going on how this evidence base can be translated into sound public health actions and the possible implications especially in sub-



Saharan Africa where the malaria scourge is most severe (Utzing *et al.*, 2001a; 2001b; Inyang-Etoh *et al.*, 2009; Boulanger *et al.*, 2007).

Because the possible emergence of drug resistance to the antihelminthic compounds used to control STH infection and schistosomiasis remains a matter of serious public health concern, the efficacy of combined treatments that use antihelminthics with differing modes of action was assessed in some of the studies reviewed in this report (Boulanger *et al.*, 2001; Albonico *et al.*, 2003; Inyang-Etoh *et al.*, 2009). The objective of this combination therapy as noted by an earlier report by Barnes *et al.* (1995) was to identify a combination that would be efficacious and at the same time could delay the occurrence of antihelminthic drug resistance to each class of drug. In addition, the adoption of combination therapy with drugs with distinct modes of action when used at early stages was shown to delay the onset of antihelminthic drug resistance (Barnes *et al.*, 1995). The efficacy of the combined administration of mebendazole 500 mg and levamisole 40 or 80 mg was therefore evaluated for the first time by Albonico *et al.* (2003) and result showed higher efficacy than either drug alone against hookworm infections. The authors noted that this was a promising result, because the combined administration of two different antihelminthic drugs could be used as the treatment of choice in this context. Similarly in a recent investigation by Inyang-Etoh *et al.* (2009) on the efficacy of a combination of praziquantel and artesunate in the treatment of urinary schistosomiasis in Nigeria, it was confirmed that the treatment of urinary schistosomiasis with the combination of praziquantel and artesunate is safe and more effective than treatment with either drug alone.

In conclusion, it is important to state that there is an urgent need to rapidly develop safe and effective new drugs to complement the existing treatment options for STH infection and schistosomiasis. Research and development of novel antischistosomal and antihelminthic drugs are warranted, but this will become feasible only through the creation of innovative and committed public-private partnerships (Bergquist, 2002; Engels *et al.*, 2002; WHO, 2006a; 2006b). In recent times efforts have been made to evaluate new antihelminthic drugs (Bethony *et al.*, 2006), these include nitazoxanide, a nitromidazole compound and tribendimidine both of which were explored as a broad-spectrum antiparasitic agents with anthelmintic properties against many soil transmitted helminths (Gilles & Hoffman, 2002; Xiao *et al.*, 2003). Although these efforts are steps in the right direction, there is however a need for the development of new generation of tools for disease control, appropriate environmental control measures and health education (Stothard *et al.*, 2006; Hotez *et al.*, 2006a; 2007; Utzinger *et al.*, 2009; Stothard, 2009). One of such new generation tools which holds the best prospect for the sustainable control of STH infection and schistosomiasis is the development of vaccines (Capron *et al.*, 2005; Hotez *et al.*, 2006b; 2008). It is proposed that the availability of appropriate antihelminthic vaccines to be used alongside drugs in an integrated interventional programme linking vaccination with chemotherapy might result in a greater success in the control of these helminth infections (Bergquist *et al.*, 2005; Hotez *et al.*, 2006a; 2006b). However there is little evidence that antihelminthic vaccines would be available in the nearest future. Finally, existing evidence indicates that mass school-based deworming is extraordinarily cost-effective once health, educational, and economic outcomes are all taken into account (Bundy *et al.*, 2009). Therefore to ensure the realization of the WHA resolution of 2001 in sub-Saharan Africa, the well being of school-age children must be made a matter of utmost priority by the governments of countries in the sub-region and pragmatic efforts must be geared towards the strengthening of health systems and services as an important component of successful disease control programmes.

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