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BREAKING THE CYCLE OF NEGLECT: REDUCING THE ECONOMIC AND SOCIETAL BURDEN OF PARASITIC WORMS IN SUB-SAHARAN AFRICA

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Executive summary

Neglected tropical diseases cause an annual loss of 17 million healthy life years globally, with 40% of these lost in sub-Saharan Africa

- Neglected tropical diseases (NTDs) are a heterogeneous group of mostly infectious diseases that largely affect poor individuals living in low- and middle-income countries. The World Health Organisation (WHO) report that globally over 1.76bn people still require interventions against NTDs. Over a quarter of those affected live in sub-Saharan Africa.

Schistosomiasis and soil-transmitted helminthiasis are the most prevalent neglected tropical diseases in sub-Saharan Africa

- The majority (86%) of global schistosomiasis cases occur in sub-Saharan Africa, and 26% of soil-transmitted helminthiasis cases. The two diseases caused a loss of about 2.1m healthy life years in 2017. The ill health caused by these diseases hampers adults' ability to work, and could adversely impact children's schooling.

Eliminating morbidity and mortality from schistosomiasis and soil-transmitted helminthiasis in Ethiopia, Kenya, Rwanda and Zimbabwe by 2030 could boost these countries' GDP by US$5.1bn in purchasing power parity (PPP) terms by 2040

- The most recent WHO roadmap for neglected tropical diseases sets targets for the elimination of both schistosomiasis and soil-transmitted helminthiasis as public health problems by 2030. Once this is achieved, the countries will need to eliminate transmission to stop these diseases returning.

- The EIU has modelled the economic impact eliminating morbidity and mortality from these diseases by 2030 and preventing their resurgence, compared with a scenario where efforts to combat them stagnate, and cases increase with population growth. We focus on four sub-Saharan African countries—Ethiopia, Kenya, Rwanda and Zimbabwe.

- Our analysis finds that this could boost productivity by US$5.1bn (PPP) between 2021 and 2040 across Ethiopia, Kenya, Rwanda and Zimbabwe. The greatest potential gains are seen in Ethiopia at US$3.2bn, followed by Kenya (US$1.3bn), Rwanda (US$0.4bn), and Zimbabwe (US$0.3bn; all figures at PPP).

- In addition, eliminating the ill health associated with these parasitic worms among school-age children in these countries could improve their ability to learn and attend school. Our estimates suggest that this could potentially benefit these children by US$1.2bn (PPP) in extra wages between 2021 and 2040 once they enter the workforce.

Continued multi-sectoral action is needed to successfully eliminate these diseases

- Achieving these targets will require concerted action, including better disease mapping data, tailoring to the local context, integration with wider public health efforts and programmes to improve sanitation.

- Progress towards the targets could be threatened, particularly as the covid-19 pandemic heaps pressure on health systems and economies. As countries approach elimination and case numbers drop, it is also important to maintain momentum to ensure sustainable elimination of these diseases.

Introduction

What are the neglected tropical diseases?

Neglected tropical diseases (NTDs) are a diverse group of diseases, most of which are communicable and caused by a wide variety of pathogens, which exist in 149 countries.[1]

NTDs are widely known to affect populations of lower socioeconomic status. They are the most common group of diseases among the 2.7bn people worldwide who live on less than US$2 a day.[2] NTDs are known to thrive in areas that lack clean water and proper sanitation, which are often in rural and remote regions.[3]

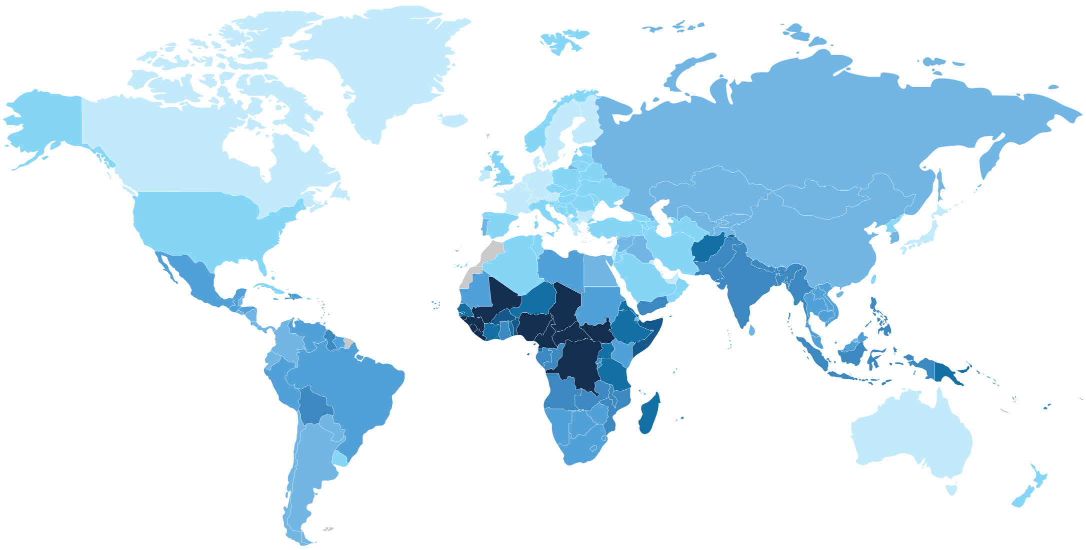
The populations who experience these diseases most acutely are the least equipped to advocate for improvements to their situation. At the same time, governments have historically been less willing to address NTDs because other notable infectious diseases (such as HIV and malaria) cause more deaths and have therefore been higher on the agenda.

> **If a community has a high burden of worms, it is a marker of poverty and poor access to healthcare and [water, sanitation and hygiene]. Universal Health Care is unlikely to be in place if there are communities that have high worm burdens.**
>
> Dr Simon Brooker, Deputy Director, NTDs at the Bill & Melinda Gates Foundation

Figure 1: NTDs collocate with poverty[4, 5]

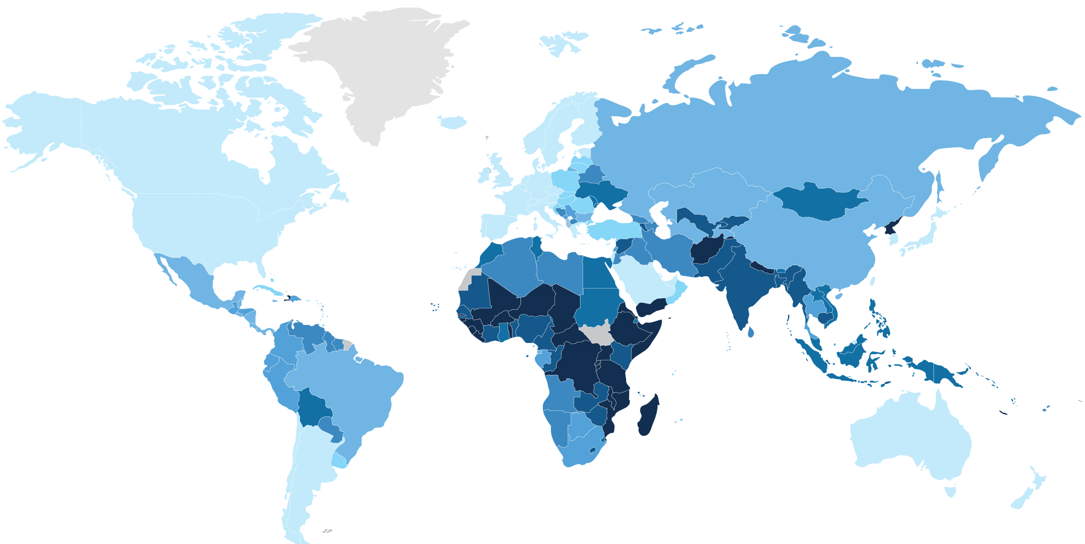
NTD burden per thousand inhabitants
Disability-adjusted life years (DALYs), 2017

>7.5 | 4.5-5.99 | 1.5-2.99 | 0.1-0.49 | No data
6-7.49 | 3-4.49 | 0.5-1.49 | <0.1



GDP per capita
thousand US$, 2017

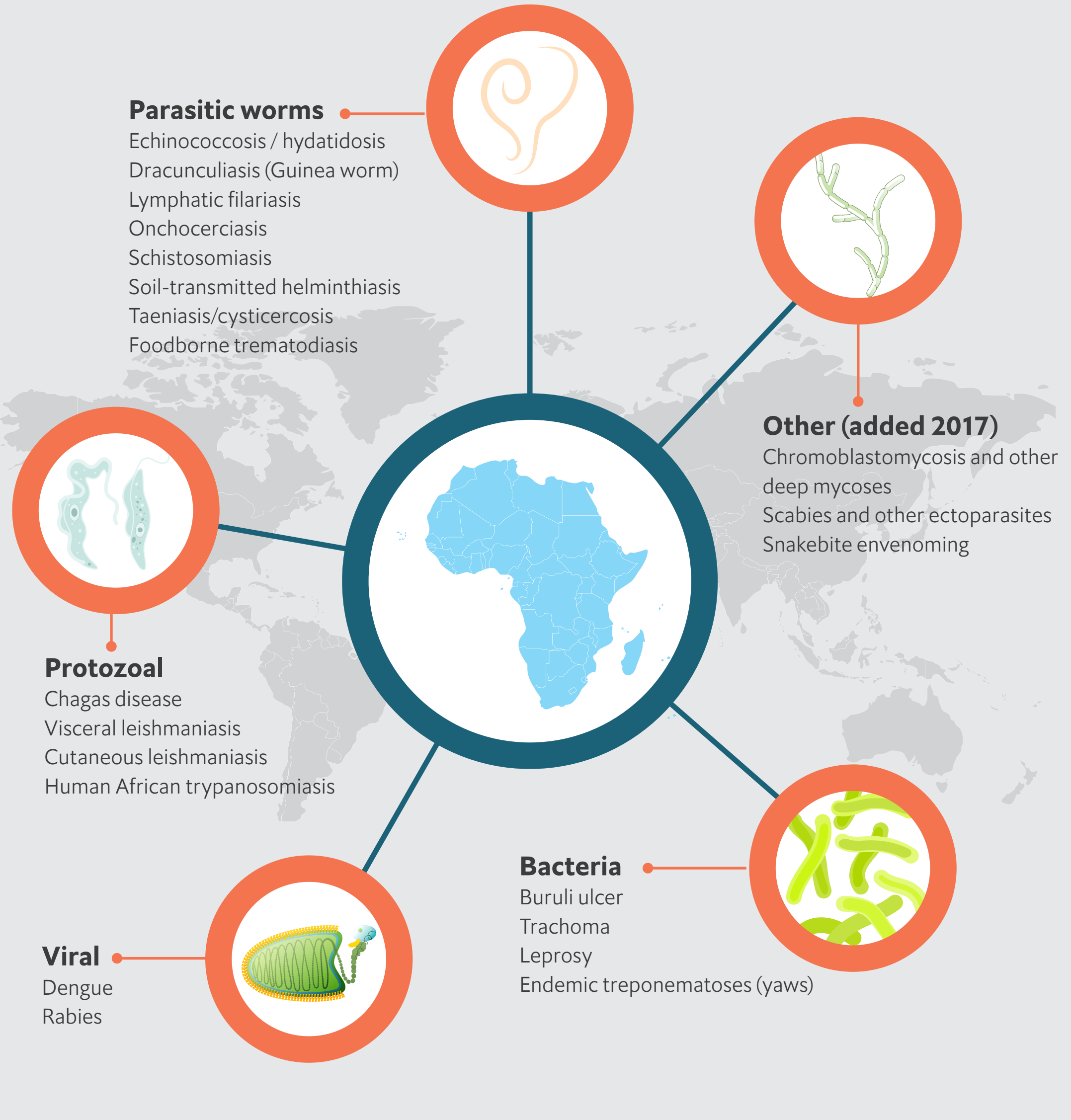
>20 | 8-9.9 | 4-5.9 | 1-1.9 | No data
10-19.9 | 6-7.9 | 2-3.9 | <1



In 2012 the WHO launched its Roadmap on Accelerating Work to Overcome the Global Impact of NTDs, in which it classified 17 diseases as NTDs, with a further three added to the list in 2017 (see Box 1).[6]

The WHO's list of NTDs reflects the diversity of this category of diseases. It includes a range of vector-borne diseases such as rabies and dengue, as well as parasitic worm infections such as schistosomiasis, diseases caused by other pathogens, and even snakebite envenoming.

Box 1: NTDs included in the WHO's Roadmap grouped by type



Globally the impact of NTDs remains considerable, with the WHO estimating that at least 1.76bn people still require interventions to treat them.[7] Data from the Global Burden of Disease (GBD) study for 2017 suggest that over a quarter of people with NTDs live in sub-Saharan Africa.[5] These diseases cause the loss of 6.7m healthy life years in sub-Saharan Africa alone, almost 40% of the global total 17m healthy life years lost (based on NTDs listed in the WHO roadmap and present in the GBD data).[5]

NTDs are most common in tropical and subtropical areas, where other environmental factors such as climate change could drastically increase transmission rates.[8] NTDs are linked to socioeconomic status in two ways: they affect individuals of low socioeconomic status and they impair the socioeconomic development of affected communities. The influence of NTDs on global health is highlighted by the inclusion of their elimination by 2030 as part of the UN's Sustainable Development Goals (Goal 3.3).

There has been increased focus on NTDs since the launch of the WHO Roadmap on Neglected Tropical Diseases 2012-20, although the burden of NTDs has been examined globally since at least 1947.[9] The aim of the WHO roadmap was to achieve the elimination of these NTDs or their reduction to a state where they were no longer considered a public health problem.

Inspired by the WHO's 2012 roadmap, the London Declaration on Neglected Tropical Diseases was created in order to focus on control and elimination of ten selected NTDs by 2020.[10] The Declaration formalised commitments made by a wide variety of partners, including numerous NGOs, national governments, pharmaceutical companies and other entities. It included commitments from drug companies to donate the drugs needed to combat NTDs. The Declaration, which reflects longstanding and successful public-private partnerships to achieve the common goal of NTD elimination, has contributed substantially to reducing the burden of NTDs around the world.

There has been progress since the 2012-20 roadmap was published: 500m fewer people need treatment for NTDs now than in 2010, and 40 countries or areas have eliminated at least one NTD.[7] However, not all of the 2020 targets will be met.

An updated WHO NTD Roadmap to cover 2021-30, including revised targets for the individual NTDs, is awaiting final approval from the World Health Assembly.[7] Renewal of the London Declaration commitments is likely to be needed to achieve the revised targets. The current covid-19 pandemic could threaten progress, as it puts a strain on national economies, health systems and the healthcare industry, including pharmaceutical companies who donate drugs. In April 2020 WHO guidance recommended that, given the findings of pandemic community-based surveys, active case-finding activities and mass treatment campaigns for NTDs be postponed until further notice.[11] The WHO updated their guidance in July 2020 to outline a risk-benefit assessment framework which countries can use to decide whether planned NTD activities should go ahead as the pandemic evolves and risks change. The guidance also describes general precautionary measures for countries to follow as they slowly begin to resume NTD activities. [12]

The International Monetary Fund (IMF) has predicted that global economies will contract by 4.9% in 2020, with those in sub-Saharan Africa shrinking by 3.2%.[13] The EIU predicts healthcare spending in US dollar terms will reduce by 2.9% in the Middle East and Africa in 2020, before increasing by 3.4% in 2021.[14] Although this increase in health expenditure may sound positive, the cost of covid-19 treatments and vaccines (if and when they come onto the market) is likely to put additional strain on already stretched healthcare budgets.

NTDs in sub-Saharan Africa

The subset of NTDs with the greatest impact in sub-Saharan Africa—in terms of population affected and as a key cause of disability and illness—are parasitic worm infections (see Box 1 and Table 1). Among the parasitic worm infections, soil-transmitted helminthiasis (STH—a group of infections including hookworm disease, ascariasis and trichuriasis) and schistosomiasis are the most widespread NTDs across the region.[15]

Fragmented data collection has made getting accurate portrayals of the prevalence and transmission trends in the region challenging. Effective prevention and control strategies depend on systematic surveillance, which has been a problem across the African continent.[16 17]

This report quantifies the economic impact of parasitic worm infections in sub-Saharan Africa, as well as describing the context and some of the challenges involved in their elimination. The analysis focuses on the most prevalent infections—STH and schistosomiasis—in four countries—Ethiopia, Kenya, Rwanda and Zimbabwe. These countries provide a cross-section of the countries within the region, with varying population size, size and growth of economy, healthcare spending, and political stability.

Table 1: Burden of the most prevalent NTDs in sub-Saharan Africa 2017[5] (in order of estimated number of people infected).

Disease	Estimated population infected	Estimated % of population affected (age-standardised)	Healthy life years lost (DALYs)
Soil-transmitted helminthiasis	235m	22.7%	0.9m
Hookworm disease	117m	12.0%	0.5m
Ascariasis	98m	8.9%	0.3m
Trichuriasis	45m	4.2%	0.06m
Schistosomiasis	123m	15.6%	1.2m
Lymphatic filariasis	29m	3.5%	0.9m
Onchocerciasis	21m	2.5%	1.3m
Cysticercosis	1m	0.1%	0.4m
Trachoma	0.6m	0.06%	0.06m
Dengue	0.4m	0.04%	0.08m
Leprosy	0.1m	0.01%	0.002m

Note: DALY = disability-adjusted life year

Epidemiological burden

This report focuses on schistosomiasis as well as STH (hookworm disease, ascariasis and trichuriasis) because of the significant burden these parasitic worms pose. Though they are both treatable and preventable these worms cause a loss of nearly 2.1m healthy life years, primarily through causing ill health rather than death.[5]

In 2017 schistosomiasis and STH affected more people in sub-Saharan Africa than any other NTD, although cases of these diseases have been decreasing.[5] The region accounts for 86% of the global burden of schistosomiasis cases and 26% of STH (ranging from 15% of trichuriasis to 51% of hookworm disease cases).

Although these diseases lead to a multitude of morbidities, their symptoms can be non-specific and not visible, as is the case with some other NTDs. As a result, individuals who are infected often do not realise that they are infected until symptoms become severe, and doctors have difficulty diagnosing the diseases owing to their non-specific symptoms. This results in a vicious cycle that, in combination with poor sanitation and lack of education about these diseases, allows them to spread.

As WHO technical director Pauline Mwinzi puts it, "We have to go to great lengths to give morbidity data visibility. When you show schistosomiasis and STH patients, the majority will appear physically normal. Surveys have to be implemented that show morbidity data."

Schistosomiasis

Schistosomiasis, a chronic disease linked to poverty, is widely endemic, particularly in sub-Saharan Africa.[18] It is transmitted through contact with water that is contaminated with schistosome larvae. The two major forms of the disease are intestinal and urogenital, and infected individuals pass schistosome eggs in their faeces and/or urine. If they get into the water system, the eggs hatch and infect water snails, which later release schistosome larvae into the water, beginning the cycle again.

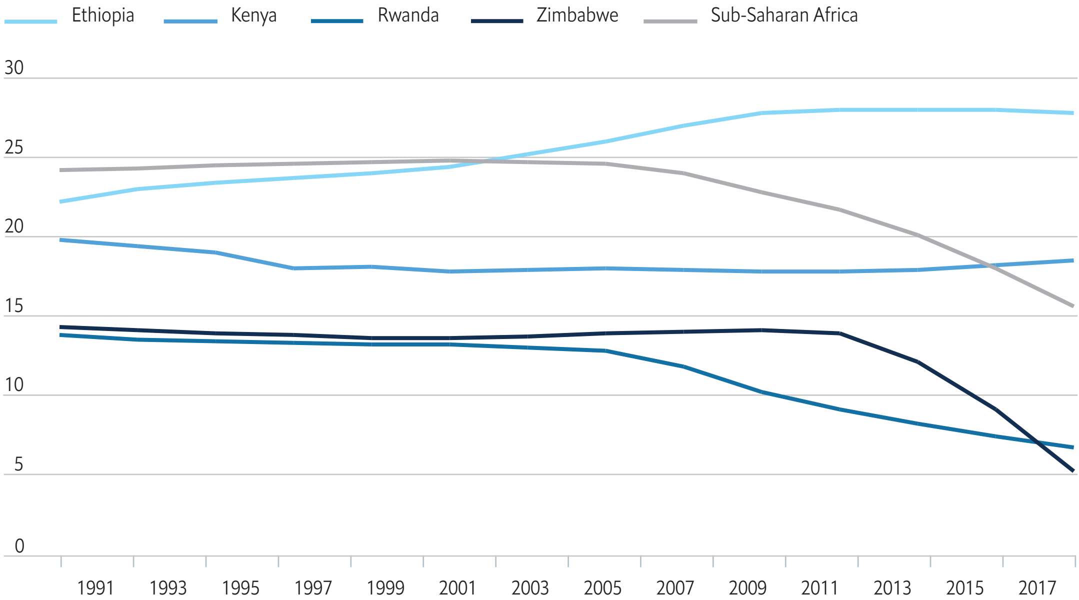
Risk factors for the transmission of the disease include a region's proximity to bodies of water, including irrigation and dams, as well as a person's occupation and socioeconomic status.[19] Climate change also impacts regional risk.

The symptoms of chronic and advanced schistosomiasis include abdominal pain, diarrhoea, anaemia, blood in the stool, liver cirrhosis, high blood pressure in the vein leading from the intestine to the liver (portal hypertension), collection of fluid in the abdomen (ascites), pain or difficulty in urination, and bladder abnormalities.[20] Schistosomiasis can also cause premature death.

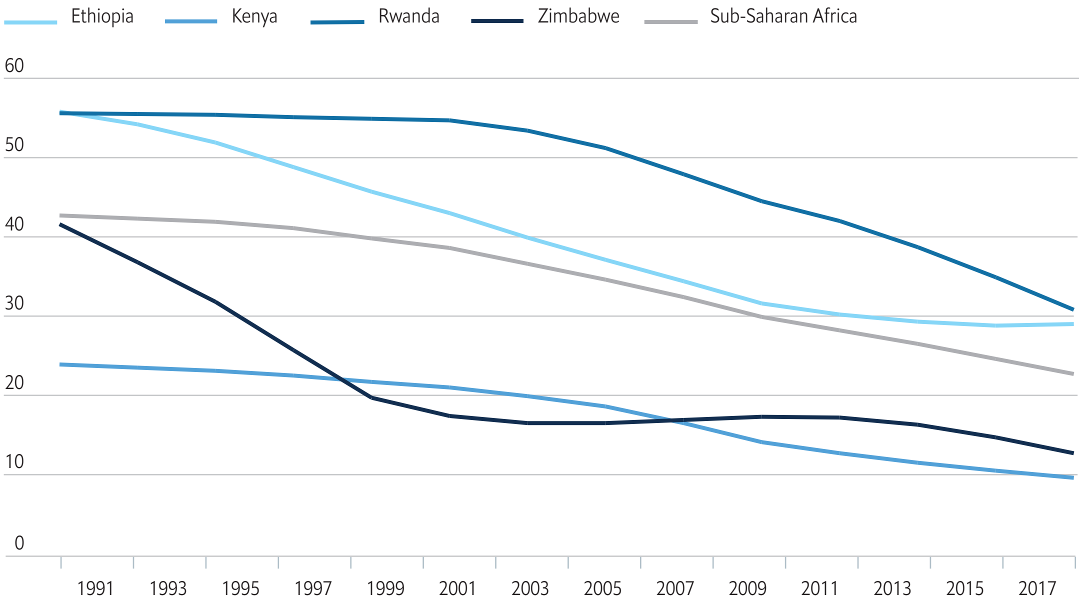
Schistosomiasis can also have negative effects on a child's development, the outcome of pregnancy and agricultural productivity, which is why infection contributes to the "bottom 500m" inhabitants of sub-Saharan Africa continuing to live in poverty.[19]

Figure 2: Trends in the age-standardised % prevalence of schistosomiasis and STH
in sub-Saharan Africa, 1990-2017[5]

Schistosomiasis



Soil-transmitted helminthiasis



The risk of infection has been decreasing since 2000 owing to control efforts (see Figure 2), but estimates suggest that 123m people in sub-Saharan Africa are still infected with schistosomiasis (about 86% of infections globally), causing the loss of about 1.2m DALYs in 2017.[5] However, underestimation of disease burden is a major problem with schistosomiasis, owing to a lack of knowledge of the symptoms of the disease.[19]

In terms of age breakdown in sub-Saharan Africa, schistosomiasis is least prevalent in the under-fives, and gradually increases with age until it peaks in the 30-49 age group.[5] Rates of schistosomiasis are higher in men than women, which may reflect occupational hazards among more male-dominated groups such as fishermen.

Soil-transmitted helminthiasis (STH)

STH in humans is most often caused by roundworms (*Ascaris lumbricoides*), whipworms (*Trichuris trichiura*) and hookworms (*Necator americanus* or *Ancylostoma duodenale*). People become infected when they come into contact with the larvae of these worms through touching soil, human faeces or water that has been contaminated with the parasites' eggs.[21] Once infected, people pass eggs in their faeces. If this is allowed to contaminate soil or water, the cycle can continue. Therefore, as with schistosomiasis, STH is associated with poor sanitation.

These intestinal worms can cause malnutrition, anaemia, stunting, impaired intellectual development and susceptibility to other infectious diseases such as HIV. Ascariasis is the only STH that can lead to premature death.

Over 4.5bn people around the world are at risk of STH infection, but there is an uneven distribution of the disease globally.[22] STH disproportionately affects populations who are typically marginalised and low-income, as evidenced by the fact that over 1bn people in resource-constrained areas of sub-Saharan Africa, Asia and the Americas are infected with at least one helminth.[22] Often individuals in these settings can be infected by more than one type of worm (polyparasitism), which can lead to higher rates of morbidity.[22]

The prevalence of STH among school-age children in sub-Saharan Africa decreased from 43.3% to 25.9% in 2017, representing a 40% reduction in this period.[5] This reduction is the product of an increased focus on large-scale deworming programmes, as well as an increase in socioeconomic development.[15]

In 2017 about 253m people in sub-Saharan Africa had STH, about 26% of the global total.[5] However, the region accounts for 45% of the DALYs (0.9m) associated with these diseases globally.

There is less of an age gradient in STH prevalence in sub-Saharan Africa than for schistosomiasis. The lowest prevalence for STH is in under-fives, but the rates are still high (16% of the age group affected). Rates then increase sharply in the 5-9 year old age group (27% affected) and reach a peak in the 15-24 age group (with about 29% of this age group affected).

Strategies for NTD control

Policy context

As well as its global NTD roadmap for 2012-20, the WHO created a regional strategic plan for NTD control in Africa, setting out five targets for 2014-20:

1. to eradicate dracunculiasis and yaws in all countries of the region;
2. to sustain elimination of leprosy and further reduce severe leprosy disabilities;
3. to eliminate lymphatic filariasis, onchocerciasis, schistosomiasis and blinding trachoma;
4. to control morbidity due to Buruli ulcer, human African trypanosomiasis, leishmaniasis, soil-transmitted helminthiasis and rabies in the region; and
5. to prevent disabilities due to Buruli ulcer, leishmaniasis, leprosy, lymphatic filariasis and blinding trachoma.

The regional objectives more broadly define the strategy of NTD control. They include scaling up access to interventions and system capacity building; enhancing planning for results, resource mobilisation and financial sustainability of national NTD programmes; strengthening advocacy, co-ordination and national ownership; and enhancing monitoring, evaluation, surveillance and research.[23]

As previously discussed, parasitic worm infections represent a significant proportion of NTDs, particularly in sub-Saharan Africa. The WHO Research Priorities for Helminth Infections identified the most important strategies in the reduction of parasitic worm infections worldwide in 2012: [24]

1. updated disease prevalence maps;
2. more sensitive diagnostics;
3. monitoring the progress of control interventions and quantifying changes in incidence of infection and disease;
4. assessing drug efficacy and promptly detecting development of drug resistance;
5. determining programme end-points (for elimination of infection);
6. post-control surveillance; and
7. developing appropriate health research policies and capacity building in disease-endemic countries to provide conducive environment and adequate expertise for sustained disease-control efforts.

The WHO has recently updated the 2012 NTD Roadmap to set ambitious goals for all NTDs, to be achieved in 2021-30.[7] The overarching goals include:

- 90% fewer people requiring interventions against NTDs;
- 75% fewer NTD-related DALYs;
- 100 countries having eliminated at least one NTD; and
- two NTDs eradicated (dracunculiasis and yaws).

The WHO has also set specific targets for each of the NTDs. The goal for schistosomiasis is elimination of the disease as a public health problem in 100% of endemic countries. Similarly, the WHO targets elimination of STH as a public health problem for 96% of endemic countries. Elimination as a public health problem is defined as reducing the burden of a disease to specified levels of moderate and/or heavy-intensity infections (under 1% for schistosomiasis and under 2% for STH).

Modelling for schistosomiasis has shown that if treatment is stopped after achieving elimination as a public health problem there is highly likely to be a resurgence in infections.[25] The same is likely to be true for other infectious NTDs. Therefore once elimination as a public health problem is achieved, countries will need to continue treatments to achieve interruption of transmission, where new infections would be reduced to zero, with minimal chance of reintroduction, reducing the need for ongoing treatment.

NTD control programmes

In 2003 the WHO began to shift the focus away from specific disease treatment and instead began focusing on the health needs of populations experiencing NTDs at the highest rates.[6] The two major interventions that came out of this new way of thinking about NTD control were preventive chemotherapy and intensified disease management. The five main strategies recommended by the WHO[6] for NTD control programmes are:

- preventive chemotherapy;
- intensified disease management;
- vector and intermediate host control;
- veterinary public health at the human-animal interface; and
- the provision of safe water, sanitation and hygiene.

Preventive chemotherapy treatment

Five NTDs can be managed using preventive chemotherapy treatment (PCT): schistosomiasis, STH, onchocerciasis, lymphatic filariasis and trachoma (all except trachoma are caused by parasitic worms). The WHO provides recommendations for PCT for these NTDs (see Table 2).[26]

Most commonly this form of treatment is given through mass drug administration (MDA) to at-risk individuals in endemic areas.[22] MDA uses two primary methods to reach affected communities: community-based distribution is carried out through static distribution points or delivering medicine door-to-door, while school-based distribution happens at schools and is specifically directed at school-age children. Both MDA methods are not reliant on a diagnosis prior to delivering medicine. In MDA programmes coverage of treatment for school-age children is often reported as the main indicator of programme success.

Historically, MDA (also referred to as deworming) programmes have not been integrated into the health system, but rather run parallel to activities of the health sector. These are vertical programmes involving pharmaceutical companies donating medications to the government, with the WHO overseeing the donation programmes. Co-ordination and dissemination are organised at the national level in order to deliver the medications to at-risk populations (most often school-age children).

The WHO has promoted mass deworming programmes for years, but in 2017 the WHO's Guideline Review Committee solidified the importance of PCT by issuing a guideline

Table 2: NTDs targeted by preventive chemotherapy[6]

Disease	Treatment	Target population	Minimum effective coverage	Frequency and duration of intervention
Lymphatic filariasis	Albendazole with ivermectin or with diethylcarbamazine citrate	Ivermectin: ≥ age 5 years Diethylcarbamazine: ≥ age 2 years	65%	Annually for at least 5 years
Onchocerciasis	Ivermectin	>Age 5 years	80%	Annually for at least 10-15 years
Schistosomiasis	Praziquantel	School-age children (SAC, ages 5-14 years) and at-risk adults	75%	Once a year, or every two to three years, depending on community prevalence, for variable duration
Soil-transmitted helminthiasis	Albendazole Mebendazole	Pre-SAC (<age 5 years) and SAC (age 5-14 years)	75%	Once or twice a year, depending on community prevalence, for variable duration
Trachoma	Azithromycin (given as part of a SAFE strategy)	>Age 6 months	80%	Annually, with the number of rounds given before review dependent on the prevalence of disease at last estimate

stating that "deworming improves the health and nutrient uptake of heavily infected children."[27] Givewell, an organisation that assesses the cost-effectiveness of different types of interventions funded by charities and donors, notes that cost-effectiveness calculations are problematic owing to weaker evidence of impact on health and life outcomes. However, Givewell includes deworming for schistosomiasis and STH in its priority programme list. The organisation estimates that the cost-effectiveness of deworming for these two NTDs is on a par with that of its other priority programmes such as malaria treatment programmes, certain immunisation campaigns and Vitamin A supplementation.[28]

Schistosomiasis treatment

Praziquantel is the only drug that the WHO recommends for the treatment of both urogenital and intestinal schistosomiasis, which many are worried could lead to drug resistance.[29] Praziquantel costs around $0.08 per tablet, and it is estimated that around 70m children at risk of schistosomiasis can be treated for about US$22m per year (although drugs are currently donated so governments do not bear this cost).[30]

Further research is needed in order to identify alternative treatments and determine the best treatment (or combination of treatments) and corresponding doses, particularly for school-age children.[20]

The epidemiology and control of schistosomiasis in sub-Saharan Africa has focused largely on infections in school-age children, with little focus on adults. There is increasing literature to suggest that infections in infants and children of preschool-age require the same attention.[31] A greater understanding of specific risk factors for infection in preschool children is needed, as is education of the mothers and caretakers of such children in order to start prevention sooner.

STH treatment

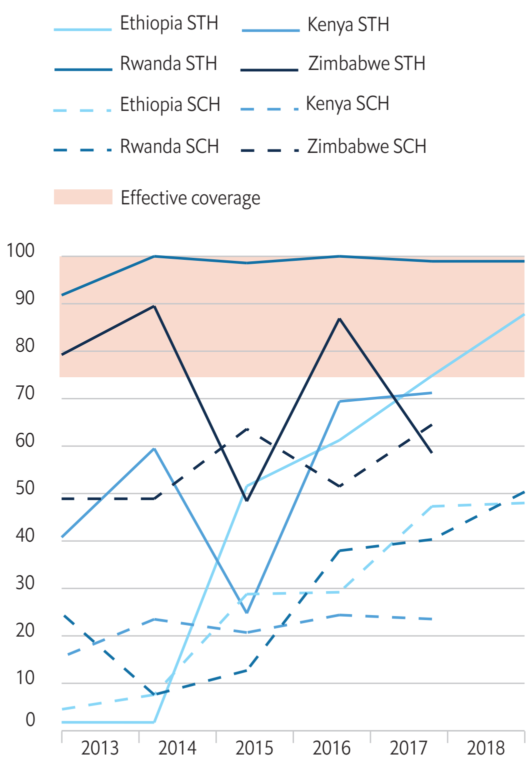
The most common treatment for STH is albendazole which is effective against ascariasis and hookworm disease.[32] Cure rates are reported to be over 75% for these forms of STH, but the efficacy of the drug for treating trichuriasis is poor.[32] Mebendazole is also recommended by the WHO for treatment of STH. Stephanie Knopp of the Swiss Tropical and Public Health Institute suggests that trichuriasis could take the longest of the helminthic diseases to eliminate because of the lack of an effective treatment.

Preventive chemotherapy coverage

In 2015 it was estimated that 123m doses of praziquantel would be needed to treat school-age children in sub-Saharan Africa for schistosomiasis, while 247m would be needed to treat the entire population.[33] Similarly, it was estimated that 126m doses of anthelmintic treatments were required per year to treat STH in the region.[15]

Across our four countries of interest (Ethiopia, Kenya, Rwanda and Zimbabwe) rates of preventive chemotherapy for STH and schistosomiasis are mostly increasing (see Figure 3).[34] However, only Rwanda and Ethiopia have achieved over 75% coverage of PCT for STH among school-age children (the level needed for deworming to be effective in eliminating these diseases as public health problems). None of these four countries have achieved this level of coverage for preventive chemotherapy against schistosomiasis in recent years according to WHO figures. To some extent this reflects differences in the target populations. Preventive chemotherapy against schistosomiasis is recommended by the WHO in adults and school-age children in endemic areas. For STH only certain groups of adults are recommended for preventive

Figure 3: PCT coverage (%) in our focus countries 2015-2018*



*SCH=PCT coverage for schistosomiasis; STH=PCT coverage for STH.
For STH the graph shows national coverage of school-age children with albendazole.

chemotherapy, so adults are not included in the national coverage figures. Because school-age children can be given preventive chemotherapy in school settings, it is easier to achieve higher coverage in this age group than adults. For schistosomiasis preventive chemotherapy coverage in school-age children alone is higher than overall coverage.

Treatment funding and donation

The last decade has seen a substantial increase in the number of organisations and amount of attention dedicated to NTDs. Among the most important initiatives have been the drug donation programmes that provide millions of infected individuals with free treatment through MDA programmes. The average reported cost for preventive chemotherapy is US$0.40 per person (2015 US dollars), increasing to US$0.70 if the cost of health ministry staff time and assets is included.[26] However, the focus on a single number does not allow for the complexities and nuances of treatment practices for a range of NTDs. What is most important is that treatments exist for this category of diseases that have demonstrated clinical and cost-effectiveness (see Table 3).

As well as funding for existing treatment and prevention options, investment is needed in other areas, for research and development (R&D) to develop new treatments and vaccines, for example. According to the latest report published by Policy Cures Research, in 2019 R&D funding was US$23.8m for schistosomiasis, US$2.7m for hookworm disease, US$2.2m for trichuriasis and US$1.7m for ascariasis. Parasitic worm infections as a whole received US$88m. Comparatively,

Table 3: Cost-effectiveness of preventive chemotherapy for selected NTDs[26]

Disease	Intervention	Setting	Target Population	2012 US$ per DALY averted, relative to doing nothing unless otherwise stated
Lymphatic filariasis	Albendazole + ivermectin	Global	All	$28 (relative to baseline elimination programme)
Onchocerciasis	Ivermectin	Africa	Areas with microfilarial prevalence 40% and above	$3-$15 (depending on prevalence, higher prevalence areas have lower cost per DALY averted)
Schistosomiasis and STH	Albendazole + praziquantel	Global	School-age children	$5-$80
		Cote d'Ivoire		$114
Trachoma	Azithromycin (MDA) + surgery for the blinding stage	Sub-Saharan Africa	95% coverage	$22-$83

Note: DALY = disability-adjusted life year; STH = soil-transmitted helminthiasis.

HIV/AIDS received nearly US$1.5bn, while tuberculosis and malaria received US$684m and US$663m respectively.[35]

Although drug donations have been an important factor, many experts in the field point to the fact that control strategies require deep and meaningful engagement with local communities as well.[36] As such, the importance of nurses and community health workers will only continue to grow if elimination targets are to be reached. Specifically, they can aid in delivering more horizontal programmes that can integrate control activities for multiple diseases and therefore reduce overall costs compared with vertical programming for each disease.[36]

Water, Sanitation and Hygiene (WASH)

MDA is not the only solution for reducing the burden of parasitic worms. Community-based interventions combining the provision of clean water, sanitation and hygiene (WASH) will also be essential components.[37] A country's economic growth alone will not be enough to eliminate the mortality that is associated with lack of access to proper WASH.[38] Sustained and directed investments must be made to the WASH sector to see lasting improvements in health. Collaboration between a country's NTD sector and WASH sector is so critical that the WHO has created various strategies and toolkits to better integrate their activities.[39]

"Behaviour change can be incorporated into MDA campaigns. The issue is that kids learn what they should do but don't have the infrastructure to implement what they have learned—especially regarding education about hygiene," suggests Peter Steinmann of the Swiss Tropical and Public Health Institute. Lessons regarding healthy behaviour could end up being wasted unless a country is willing to invest in its WASH sector. A symbiotic relationship between WASH and NTDs will be a vital element of progress in eliminating parasitic worms.

Vector control

As schistosomiasis is spread by a vector (water snails), vector control remains an area of interest. However, this is difficult to manage across a country in a tropical environment, as Dr Knopp explains: "You must first find all water bodies, which can be in remote and hard to reach areas. The toxic molluscicide can kill fish and other water creatures so this can't really be the solution. There needs to be more research into less harmful molluscicides [that] can be more specific and safe." Current molluscicides date back decades and are often expensive and dangerous, despite WHO recommendations to control the transmission cycle as part of an integrated strategy.[40]

Integration, education and innovation

Not only is national scale-up of preventive chemotherapy important, so is the integration of MDA programmes. Most of the cost of operating MDA programmes comes from treatment delivery rather than the drugs themselves, which means that administering more than one drug at a time is extremely cost-effective.[41] The incremental cost is greatly reduced in an integrated approach, which renders it cost-effective to operate MDA programmes in communities with a lower prevalence where doing so would have previously been too costly.[41]

Community support for an integrated approach is strong, largely owing to the time and cost savings.[42] This integrated approach could be particularly useful in remote areas with limited access to health services.[42] Qualitative studies have demonstrated that community support for integrated approaches is strong, with 85% of focus group discussions concluding that an integrated approach would result in a "two-for-one" health treatment.[42] Although integration has been occurring, there is continued debate around integrating NTD programmes into broader health-sector activities, as there is concern that it could lead to de-prioritisation.

Conversely, there is consensus about gaps in treatment and control, including acknowledgement of a need for regular and widespread MDA in school children, the development of novel and alternative antihelminthic drugs and vaccines, broader health education around NTDs and their risk factors, and better access to clean water and improved sanitation.[32]

In terms of education, the key individual factors known to prevent uptake of preventive treatment and services for schistosomiasis in sub-Saharan Africa are limited knowledge, negative attitudes and risky water-related practices among community members.[43] School-age children and their caregivers are identified as the primary populations in which transmission of the disease occurs.

It is important to adapt health education to make it more comprehensive by using standardised training tools in order to improve knowledge, attitudes and practice in relation to schistosomiasis treatment and control. It is also crucial to involve caregivers in the educational process around schistosomiasis, as they should reinforce lessons learned through health education. Re-orientating the global control strategy to emphasise the role of adults would help to progress towards local elimination.[15]

The same principle of relative uniformity holds true for the factors that facilitate MDA. One study found that the following factors shape the implementation of MDA programmes for lymphatic filariasis in sub-Saharan Africa:

- awareness creation through innovative community health education programmes;
- creation of partnerships and collaborations;
- integration with existing programmes;
- creation of morbidity management programmes;
- motivation of community drug distributors through incentives and training; and
- management of adverse effects.[44]

These factors are widely applicable to all MDA programmes for NTDs, and if implemented could result in more successful MDA programmes. One such factor that would be widely beneficial across MDA programmes is the use of predictive risk mapping. Interest is growing in the use of this as a way to target the scaling-up of preventive chemotherapy and surveillance, which could bolster elimination efforts.[15]

One issue with the way that control and elimination campaigns are currently measured is that they often do so using only a single metric. Countries will often measure their control and elimination efforts in terms of prevalence alone (or number of persons receiving treatment) because other data are complicated and costly to collect. However, a more effective and comprehensive way to measure progress on NTDs would be to take into consideration factors such as endemicity, species of parasite, and the relationship between infection and morbidity in the specific context where control and elimination campaigns are taking place.[45]

Intra-country variation in prevalence of any particular NTD is often high, suggesting a need to consider local epidemiological data more frequently.[45] Simple prevalence measures also fail to capture the complications relating to NTDs that endure after they have been cured. For instance, an individual may experience genital schistosomiasis or an enlarged liver or spleen for years after intestinal schistosomiasis has been cured.[45] These sorts of complications can greatly contribute to the burden of disease in any particular country, and should be measured accordingly.

In a different vein, yet just as important to the control of NTDs, is the issue of novel prevention measures. Vaccine development for NTD pathogens has been slow to advance for a multitude of reasons. Primarily, there are difficult technical issues to overcome, including antigen discovery, process development, preclinical development, conducting clinical trials in low-resource settings and designing vaccines with co-infection in mind.[46] Further exacerbating the technical barriers is the issue of cost, underscored by the fact that the primary recipients of the vaccines are people living below the World Bank's defined poverty line.[46] As a result of the lack of a traditional market for these vaccines, the R&D for these so-called "anti-poverty" vaccines has lagged behind.[46]

Expert opinion: Eliminating transmission of parasitic worms in sub-Saharan Africa

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It cannot be business as usual. It has to be business ‘unusual’ for a real difference to be made. We must be eager to embrace evidence-based realities. Many stakeholders tend to be comfortable with morbidity control as the goal, happy to achieve a sufficiently low disease prevalence. Those perceptions interfere with the elimination agenda. We even see an apparent reluctance to embrace strategies that will enable us to break transmission, strategies that aim to go beyond morbidity control.

Dr Sultani Matendechero, Head, Division of Vector Borne and Neglected Tropical Diseases, Ministry of Health Kenya

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We need to generate the evidence to show that elimination of transmission is technically feasible and financially sustainable. The case for eliminating disease is strong—but the technical feasibility needs to be built up.

Dr Simon Brooker, Deputy Director, NTDs at the Bill & Melinda Gates Foundation

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In the last ten years we have had tremendous improvement in the health of the children. We’ve dramatically reduced morbidity. But we cannot stop the control interventions now. If we stop, we lose all the benefits. Endemic countries need to progressively adapt the intervention to the changing epidemiology of the parasite and at the same time progressively became independent in procuring and distributing anthelminthic medicines. We’re a long way away, but it is essential.

Dr Antonio Montresor, Medical Officer, in charge of soil-transmitted helminthiasis, Department of Neglected Tropical Diseases, WHO

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A major success is that MDA programmes have been massively scaled up in recent years. Presently, MDA is effective in controlling morbidity, but as we move toward elimination and interruption of transmission we need adaptive intervention strategies. Certain hotspot areas need targeted interventions in addition to MDA (snail control, behaviour change etc.). Other areas are receiving drugs even if they have low prevalence rates, which may contribute to treatment fatigue. Interventions in low-endemic areas are needed that are different to MDA, maybe using strategies from malaria programs such as surveillance-response.

Dr Stefanie Knopp, project leader in the Ecosystem Health Sciences Unit, Swiss Tropical and Public Health Institute

The economic benefits of elimination

It has been estimated that meeting the WHO's 2020 targets for the five NTDs that can be treated by preventive chemotherapy could provide US$564bn (PPP) in productivity gains globally between 2011 and 2030.[47] Out-of-pocket costs avoided by the population in this period are estimated to be much lower, at about US$1.7bn (PPP). Costs to funders in this period are estimated to be US$9bn, giving a return on investment of US$27-43 for every dollar invested (at market exchange rates).

Looking to update and add to this overall analysis, we have calculated potential productivity gains from achieving the new 2030 WHO targets for schistosomiasis and STH specifically in our four countries of interest (Ethiopia, Kenya, Rwanda and Zimbabwe). We have operationalised this in the model as achieving zero morbidity and mortality from these diseases in 2030 and preventing their resurgence, in line with a similar approach taken in the study modelling the impact of meeting the WHO's 2020 targets.[47] For all analyses, the scenario in which WHO targets are achieved is contrasted with a scenario where efforts to reduce these worms stagnate, allowing numbers of cases to grow in line with population growth.

Our analysis focuses on the potential impact on adults' current and future productivity (ability to contribute to GDP) through reducing morbidity and mortality associated with these diseases. We also assess the potential impact of educational benefits among school-age children on earning potential once they enter the workforce. The impact is calculated for the period 2021-2040 in order to capture benefits related to reduction in cases of irreversible morbidity associated with these diseases, which will reduce more slowly than cases of reversible morbidity.

Methods are based on the approaches used by Redekop et al. 2017 (morbidity and mortality), Kirigia and Muthuri 2016 (mortality), and De Neve et al. 2018 (educational impact).[47-49]

Figures are expressed in US$ at purchasing power parity (PPP, sometimes called international dollars) to prevent irrelevant variations in exchange rates distorting comparisons between countries or years. Values in US$ PPP take into account the purchasing power of different local currencies when converting into US dollars.

Impact on productivity

Our analysis suggests that the productivity gains associated with meeting the WHO's NTD targets for 2030 could result in GDP gains of US$5.1bn at PPP (US$1.9bn at market exchange rates) between 2021 and 2040 across Ethiopia, Kenya, Rwanda and Zimbabwe (see Figure 4).

The vast majority of this (98%) would come from reductions in morbidity, with healthier adults being able to work more and contribute more to the economy. Schistosomiasis and STH each account for about half of the impact (53% and 47% respectively, see Figure 5). Within STH, hookworm disease has the biggest impact (39% of overall gains) with trichuriasis and ascariasis trailing behind (accounting for 4% each).

When looking at the impact by country, Ethiopia, the largest country and the country with the largest number of cases, can expect the largest gains (US$3.1bn), followed by Kenya (US$1.3bn), Rwanda (US$0.4bn) and Zimbabwe (US$0.3bn; all figures in PPP terms).

Figure 4: Impact of achieving 2030 WHO targets: GDP gains 2021-40 (US$ billion at PPP)

Horizontal red bars indicate central value, and vertical grey bars indicate upper and lower limits based on uncertainty intervals for prevalence figures from the 2017 Global Burden of Disease study.

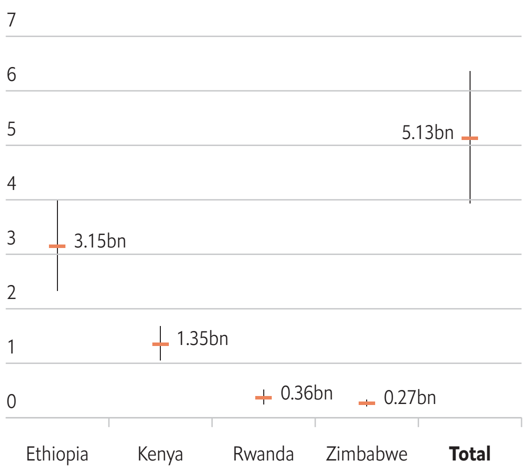
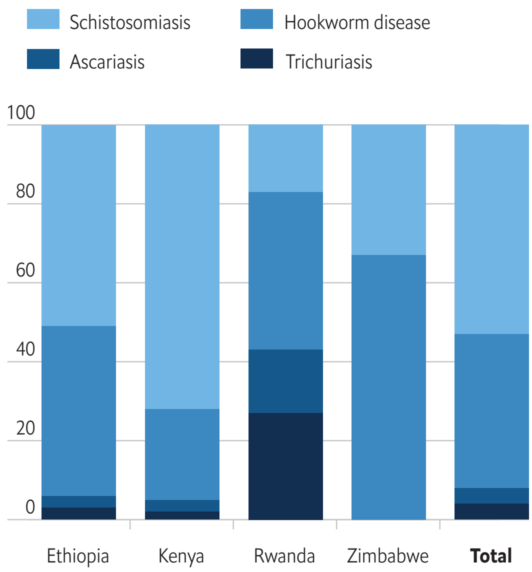


Figure 5: Impact of achieving WHO 2030 targets: Proportion of productivity gains (%) attributable to each disease, 2021-40



Impact on earning potential

The extent of any impact of deworming on children's education is controversial. Although some research has shown an impact, a review that pooled available evidence (most recently updated in 2019) concluded that regular deworming does not improve a range of outcomes, including cognition and school performance.[50] The latter study stated that the evidence of an impact on school attendance was inconclusive, owing to inconsistencies and concerns around quality. However, this review has in turn been criticised by researchers in the field for over-reliance on study types more commonly used in clinical medicine (randomised controlled trials) and not including rigorous social science evidence.[51]

With this in mind, we acknowledge that our estimation of potential benefits from reducing the burden of parasitic worms in school children depends on the assumption that doing this does carry educational benefit. This assumption seems reasonable given that the conditions needed to achieve the WHO targets are broader than deworming alone—less poverty and inequality, and better sanitation. Achieving these changes is likely to engender wider benefits for children's health and education that surpass those estimated in studies of deworming alone. However, in light of the controversy, we have selected assumptions to give a conservative estimate of potential educational and therefore income benefits.

Our calculations are based on the approach used by de Neve et al. in calculating the potential impact of deworming on educational attainment and therefore later earning

Figure 6: Impact of achieving 2030 WHO targets: Gains in income 2021-40 through better education (US$ billion at PPP)

Horizontal red bars indicate central value, and vertical grey bars indicate upper and lower limits based on uncertainty intervals for prevalence figures from the 2017 Global Burden of Disease study.

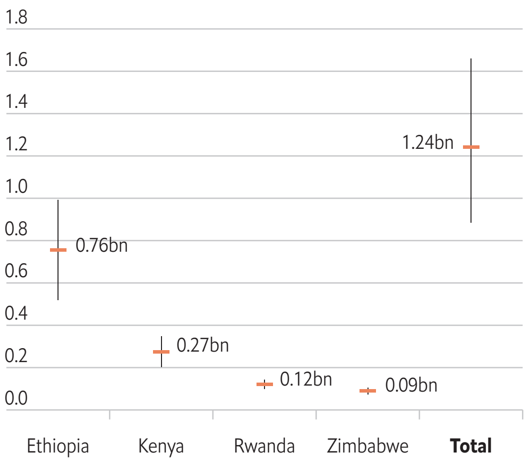
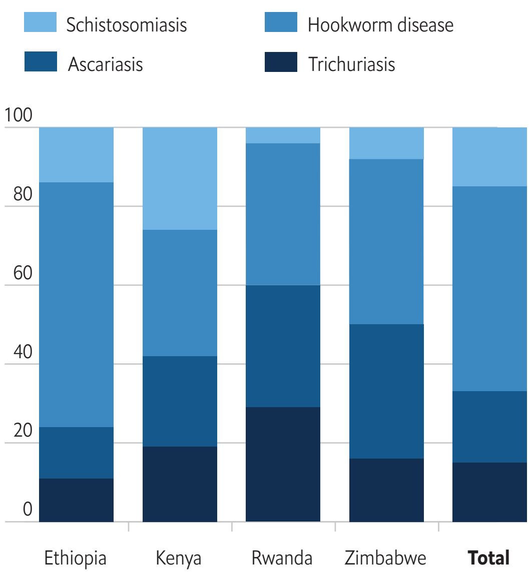


Figure 7: Impact of achieving WHO 2030 targets: Proportion of income gains (%) attributable to each disease, 2021-2040



potential.[49] The impact on educational attainment is based on the long-term findings of a controlled trial in Kenya that compared groups receiving more or less deworming. We have used conservative assumptions around this gain (a maximum of 0.15 of a grade gained over ten years) and the wages of the individuals affected.

Overall, our analysis suggests that meeting the WHO's targets for 2030 in our four countries of interest could result in US$1.2bn at PPP (US$0.5bn at market exchange rates) in greater earnings between 2021 and 2040 (see Figure 6).

In terms of where these gains are achieved, the greatest gains are seen in Ethiopia (US$0.8bn), followed by Kenya (US$0.3bn), Rwanda (US$0.1bn) and Zimbabwe (US$0.09bn; all figures in PPP terms).

These gains are predominantly achieved through elimination of STH (85% of gains), particularly hookworm disease (51%).

Conclusion: the way forward

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The ultimate intervention strategy is economic development and adequate access to WASH —but we need targeted treatment strategies to reduce morbidity associated with infection while these changes occur.

Dr Simon Brooker, Deputy Director, NTDs at the Bill & Melinda Gates Foundation

It can be easy to overlook the significant short- and long-term morbidity caused by parasitic worms, as they cause relatively few deaths compared with other tropical diseases. The symptoms caused by parasitic worm infections can be non-specific and therefore hard to attribute, which also makes generating political will challenging. However, these diseases do have considerable negative impact on people's health and productivity.

Our analysis indicates that large economic gains are possible in Ethiopia, Kenya, Rwanda and Zimbabwe—through increased productivity and wage earning—as a result of meeting the WHO's 2030 goals for parasitic worm elimination.

Below we list some principles for reducing the human and economic burden of these diseases:

- To maximise the effectiveness and efficiency of elimination programmes, they need to be **tailored to the local context**. This entails geographically targeting at-risk regions and ensuring that programme messaging is tailored to the population of focus (children, for example). Targeting specific regions within countries is only possible with robust and up-to-date data, which is a challenge in many countries in sub-Saharan Africa.
- The multiple causal facets of these diseases—including poverty, behaviour and sanitation—create the necessity for **co-ordinated, multi-sectoral strategic action**. In the past, parasitic worm elimination programmes have often been siloed; instead, they should be integrated into broader health efforts—integration with sanitation programmes would bring additional benefits. Aligning with sanitation programmes could also generate indirect political support for tackling parasitic worms. Mass drug administration programmes cannot resolve these broader public health issues, meaning that they cannot tackle the major causes of disease.
- Sustainability of programmes is challenging to maintain, especially with a reliance on external, cyclical funding, which can fluctuate. **Greater integration into public health and sanitation programmes** of measures to combat the impact of parasitic worms could also assist governments in taking greater control of programmes, as well as potentially reducing dependence on donor funding in time.

- There is also a sustainability challenge common to all successful disease prevention programmes—**maintaining political will, funding and attention** when your programme is having the desired effect and reducing the public health problem created by these diseases. This problem is particularly acute for parasitic worm infections that will re-emerge if deworming programmes are scaled back or interrupted, especially where the causes of these infections are not being adequately addressed.

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Appendices

Appendix 1: Methods overview

Project methods overview

The project began with a pragmatic literature review to identify key themes regarding the health and economic implications of parasitic worms in sub-Saharan Africa. These themes guided the discussion at an expert panel, made up of regional and country-level experts. Interviews with key opinion leaders provided additional practical insights and examples to enrich the analysis. The findings of the literature review, expert panel discussion and interview findings informed the development of a model to quantify the impact of parasitic worms in the region.

Literature review

The structured literature search identified key recent literature by interrogating selected databases and grey literature sources for papers related to parasitic worms in sub-Saharan Africa, particularly the diseases of focus. The search covered the effects of parasitic worms at the individual, community, and national level in order to better understand and measure their burden. Literature relating to the policy environment, best treatment practices, and barriers to addressing the issue was also retrieved.

A search was conducted on 22 January 2020 using Embase.com—which includes Embase and Medline bibliographic databases—using a combination of thesaurus and free text terms (see below for search strategy). The search terms included parasitic worms, examples of the diseases that worms cause (e.g. schistosomiasis) combined with the geographical area (sub-Saharan Africa). Limits to the search in Embase.com were date (2010-2020) and language (English). This search was supplemented by a more targeted search for related economic literature.

Embase.com search strategy

No.	Query Results	Results
#15.	#9 AND #12 AND [2010-2020]/py AND [english]/lim	791
#14.	#9 AND #12 AND [2010-2020]/py	798
#13.	#9 AND #12	11,325
#12.	#10 OR #11	251,183
#11.	'sub-sahara* africa':ti,ab	23,605
#10.	'africa south of the sahara'/de	13,594
#9.	#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8	238,917
#8.	'guinea worm':ti,ab	369
#7.	drancuncul*:ti,ab	11
#6.	schistosomiasis:ti,ab	18,344
#5.	helminthiasis:ti,ab	1,926
#4.	helminth:ti,ab	10,616
#3.	'parasitic worm*':ti,ab	735
#2.	'helminthiasis'/exp	134,607
#1.	'helminth'/exp	169,126

Google advanced searches were conducted between 20 and 24 January 2020. Keywords used were similar to the Embase.com search with the addition of terms for review (e.g. systematic review, literature review, research review). WHO, The London School of Hygiene and Tropical Medicine and UNICEF websites were searched via Google advanced searches.

Grey literature was searched in order to retrieve guidelines, policies, and frameworks which were not listed in scientific databases. There was no date restriction on the search, but it focused on gathering the most recent and relevant literature.

Expert panel meeting

The EIU convened a panel of experts to build upon the findings of the literature review and guide the development of the economic model. The panel consisted of key stakeholders with both national and regional-level perspectives on parasitic worms in sub-Saharan Africa.

The panel comprised the following experts:

- Dr Amadou Garba Djirmay, Scientist/ Schistosomiasis, WHO Department of Control of Neglected Tropical Diseases
- Dr Rachel Nugent, Vice President and Director, Center for Global Noncommunicable Diseases, RTI
- Dr Maria Robollo, Team Leader, Expanded Special Project for Elimination for Neglected Tropical Diseases, WHO AFRO
- Dr Eugene Ruberanziza, END Fund Project Manager/NTD Technical Advisor, Rwanda Biomedical Center, Ministry of Health, Kigali, Rwanda
- Judit Rius Sanjuan, Policy Specialist, Health Technologies, UNDP HIV, Health and Development
- Dr Wilma Stolk, Assistant Professor, Department of Public Health, Erasmus MC
- Dr Hugo C Turner, Lecturer, MRC Centre for Global Infectious Disease Analysis, Department of Infectious Disease Epidemiology, School of Public Health, Imperial College London

The expert panel discussed the literature review findings, helped refine categories to include in the analysis, provided guidance on metrics that capture key aspects and the best sources, informed the research team about the barriers for making the case locally for further investment, identified the critical issues for specific country environments, discussed the available policy levers and provided existing cases of success.

The meeting was moderated by the Economist Intelligence Unit (EIU).

Interviews

The following global, regional and national experts in parasitic worms were interviewed to gather additional insights into practice, on-the-ground challenges and methodological insights relating to the economic model.

- Dr Antonio Montresor, Medical Officer, in charge of Soil Transmitted Helminthiasis, Department of Neglected Tropical Diseases, WHO
- Dr Peter Steinmann, Project Leader, Swiss Tropical and Public Health Institute
- Dr Pauline Mwinzi, Technical Officer, SCH and STH, ESPEN, WHO AFRO

- Dr Simon Brooker, Deputy Director, NTDs at the Bill & Melinda Gates Foundation
- Nebiyu Negussu, Director, Neglected Tropical Diseases, Children's Investment Fund
- Dr Stefanie Knopp, SNSF PRIMA Grantee, Project leader in the Ecosystem Health Sciences Unit, Department of Epidemiology and Public Health, Swiss Tropical and Public Health Institute
- Professor Nicholas Midzi, National Institute of Health Research, Ministry of Health and Child Care, Harare, Zimbabwe
- Dr Sultani Matendechero, Head, Division of Vector Borne and Neglected Tropical Diseases, Ministry of Health Kenya

Economic modelling and analysis

Our model looked to quantify the economic impact of schistosomiasis and STH in sub-Saharan Africa, using four countries as examples (Ethiopia, Kenya, Rwanda and Zimbabwe). Assumptions and methods are described in Appendix 2.

Acknowledgements

This work was commissioned by the END Fund and conducted independently by the EIU. The EIU research team comprised Elly Vaughan, Alicia White, Taylor Puhl and Angela Mazimba. Searches were carried out by Caroline Coomber, the report was copy edited by Paul Tucker, and proofread by Bettina Redway. Advice on modelling was provided by David Tordrup. The findings and views expressed in this report are those of the EIU and do not necessarily reflect the views of expert panel members, interviewees or project sponsors.

Appendix 2: Economic modelling methods

We modelled the economic impact of schistosomiasis and STH in terms of:

- Loss of adult productivity due to morbidity associated with these worm infections.
- Loss of adult productivity due to mortality associated with these worm infections.
- Loss of future earnings due to reduced educational attainment (grades of school completed) as a result of these worm infections.

Our approach to modelling these impacts was based on that used by Redekop et al. 2017 to assess the global economic impact of meeting the WHO's 2020 NTD targets.[47] We updated this analysis to look at the potential economic impact of achieving the WHO's proposed updated targets for 2030 in our four countries of interest (Ethiopia, Kenya, Rwanda and Zimbabwe). The model compared two scenarios:

- **Targets hit scenario:** WHO targets for 2030 are achieved in all four countries of interest with no resurgence between 2030 and 2040.
- **Counterfactual scenario:** Efforts to combat worm infections remain at current levels, resulting in static rates of the diseases and growth in the number of cases in line with population growth.

The losses associated with each scenario were calculated, and the difference between the two scenarios used to estimate the benefits that would be gained from hitting the 2030 targets. Benefits were estimated for the period 2021-2040, as the benefits for irreversible morbidity take longer to accrue than for reversible morbidity (as number of cases will not decrease as quickly).

Based on discussions with disease experts, including experts from the WHO, Redekop and colleagues assumed that elimination of schistosomiasis as a public health problem would mean a reduction of prevalence of reversible and incidence of irreversible sequelae of the disease to zero.[47, 52] As such we assumed that with the updated WHO targets morbidity and mortality with schistosomiasis and STH would reach zero in 2030. We also assumed a zero prevalence of morbidity (and therefore zero impact on educational attainment) in schoolchildren from 2030 for our analyses of impact on future income. Sensitivity analyses altering the target level to 0.5% of most recent (2017) levels of morbidity and mortality between 2030 and 2035, and zero from 2036 onwards had a negligible impact on the results (reducing gains by less than 1% of the total).

A sigmoid curve was used to model the progression of rates to the target. This reflects the assumption that changes in rates may be slower at the start of the period while more intensive efforts to eliminate these diseases ramp up, and also at the end of the period once there are fewer cases.

Assumptions and methods for each area of the analysis are described in greater detail below. For morbidity methods are based on Redekop et al. 2017,[47] for mortality methods are based on Redekop et al. 2017[47] and Kirigia and Muthuri 2016,[48] and for education the methods are based on De Neve et al. 2018.[49]

Figures are expressed in US$ at purchasing power parity (PPP) – also known as International $. PPP is a way of presenting monetary values so that variations in market exchange rates do not distort international comparisons or year-on-year comparisons. A value in US$ PPP takes into account the purchasing power of different currencies when converting into US dollars.

To reflect the fact that these diseases often impact the poorer members of society, the analyses used GDP per capita and wage figures for the lowest income quintile (estimated using World Bank data on income splits). As a conservative assumption, our analyses utilised flat GDP and salaries from 2018 in the base case. This approach was taken by Redekop et al. 2017 and is taken in WHO assessments of investment cases. However, it may underestimate potential benefits in countries where the economy is growing. As a sensitivity analysis we utilised the Economist Intelligence Unit (EIU) long-term forecast of GDP growth for Kenya (whose forecast is available to 2040, for other countries only shorter-term forecasts are available), to look at the impact of predicted economic growth.

Table 4 summarises some of the key assumptions/variables utilised in the model and their sources or values. Disease data was the most recent available from the Global Burden of Disease (GBD) study (2017) at the time of the analyses. Data from the GBD study was utilised as it provided consistently calculated estimates of disease and morbidity prevalence across countries and years. As such the first year of modelled data was 2018, and 2018 was used as the base year for analyses.

Table 4: Key variables used in the model

Variable	Source/value
Prevalence of schistosomiasis and STH, related morbidity and deaths	GBD 2017 data[5]
Productivity losses associated with individual disease sequelae	Redekop et al. 2017[47]
Nature of individual disease sequelae (reversible or irreversible)	De Vlas et al. 2016[52]
Population growth	UN World Population Prospects 2019[53]
GDP per capita	EIU Data Tool[4]
Income share in the lowest income quintile	The World Bank[54]
Life expectancy	WHO[55]
Excess mortality	5% (de Vlas et al. 2016)[52]
Mean nominal monthly earnings	International Labour Organisation (ILO)[56]
Labour force participation (rural)	ILO modelled estimates[56]
Unemployment rates (rural)	ILO modelled estimates[56]
Additional grades of schooling gained from being worm-free	Baird et al. 2016[51]
Impact of an additional year (grade) of schooling	Montenegro & Patrinos 2014,[57] Patrinos & Psacharopoulos 2020[58]
Discount rate for future losses	3%
Working age (and age of contribution to GDP)	15+

Other data was utilised at 2018 values or most recent data available adjusted as needed. Analyses were carried out by sex and then values summed to give overall losses for each country and disease.

Productivity losses due to morbidity

Analyses were split into those for reversible sequelae (complications such as anaemia) and irreversible sequelae (complications such as ascites due to schistosomiasis). The sequelae modelled were those for which data is provided by the GBD, which were associated with productivity loss in Redekop et al. 2017, who based these figures on a systematic review of the evidence by Lenk et al. 2016.[47, 59]

For reversible morbidity, in each scenario the total number of cases projected for each sequela for each year was multiplied by the productivity loss associated with that sequela (see Table 5 for individual sequela and their associated productivity losses) and the GDP

Table 5: Sequelae modeled and their associated productivity losses

Sequela	Annual productivity loss
Sequelae associated with schistosomiasis	
Anaemia	7%
Dysuria	1.6%
Hepatomegaly	3%
Hydronephrosis	1.6%
Mild diarrhoea	3%
Ascites*	100%
Bladder pathology*	1.6%
Hematemesis*	100%
Sequelae associated with STH	
Heavy infestation (of any of the soil-transmitted helminths)	6%
Anaemia due to hookworm disease	6%

*Irreversible sequelae

per capita in the lowest income quintile to estimate losses, before applying discounting. The total difference between the targets hit and counterfactual scenarios was calculated for the period 2021 to 2040. This period was selected as it captures the impact of reduction of both reversible morbidity (which accrues up to the 2030 target), and also irreversible morbidity (which takes longer to accrue as the number of prevalent cases drops more slowly).

For irreversible sequelae, numbers of people affected will depend on incidence rate (i.e. new cases arising) and also deaths among people with the sequela. As no incidence figures are available for these sequelae, incidence was estimated based on change in number of cases between 2016 and 2017 and number of deaths expected among prevalent (pre-existing) cases in this period (based on age profile of the cases, WHO country specific life expectancy data, and excess mortality rate). The number of new cases was divided by the overall population number to obtain an incidence rate. For Zimbabwe the reduction in the number of cases of bladder pathology due to schistosomiasis in recent years according to GBD 2017 data was larger than would be expected for an irreversible sequela. Therefore, a new case rate was estimated based on the average for the other countries where bladder pathology due to schistosomiasis is present (Ethiopia and Kenya).

In the targets hit scenario, the new case rate was projected to decrease to zero in 2030 in a sigmoid curve (as for the number of cases of reversible sequelae). In the counterfactual scenario, the new case rate was projected to remain stable (as for the prevalence rate of reversible sequelae), so that the number of cases increased with population growth. Total cases in each year in both scenarios were calculated based on new cases arising and expected deaths among prevalent cases in each year period.

Productivity losses due to mortality

To calculate the future losses to the economy due to deaths from schistosomiasis and ascariasis (the only STH that causes death), we used a human capital approach similar to that used in Kirigia and Muthuri 2016.[48] This method calculates the amount that a person could have contributed to the economy in terms of GDP had they not died prematurely. These losses in the macroeconomic outputs of countries result from the erosion of future labour and productivity, as well as the reduction in investments in human and physical capital formation.

Losses from deaths accrue in all years subsequent to the deaths up to the life expectancy of the person who died (based on average life expectancy in their age group). In order to solely look at the value of losses for the period 2021-2040, we calculated the discounted present value of future losses up to 2040 arising from deaths occurring in each year up to 2040 (the end of the 'term'). These values were discounted back from the year of death to the base year of 2018 and summed.

Income losses due to impact on schooling

The study by De Neve et al. 2018 calculated the potential impact of deworming in Madagascar.[49] Part of their analysis looked at the potential impact of deworming on educational attainment and therefore future earning capacity.

They used an estimate of the additional years of schooling gained with deworming from a study by Baird et al. 2016.[51] This study was based on a quasi-randomised trial in Kenya, which allocated schools to either earlier or later receipt of mass deworming. The treatment group received just under 2.5 years of additional deworming compared to the control group and achieved an average of 0.15 additional grades of schooling compared to the control group. As mass deworming interventions treat everyone regardless of infection status, this average would include those with worms who would be expected to directly benefit and those without worms, who would not be expected to directly benefit. Therefore, this average is likely to be a conservative estimate when applied solely to a population with worms.

In general, greater levels of education are associated with higher salaries once a person enters the workforce. De Neve et al. used estimates of the wage increment associated with an additional year of schooling for Madagascar to predict how deworming would impact on dewormed children's salaries over a 20-year period.

Based on the method of De Neve et al. we used these figures to calculate the potential impact of reducing the number of children affected by schistosomiasis and STH in the period 2021-2040 through hitting the WHO targets. As a conservative assumption (similar to De Neve et al.) we assumed that each child affected by worms would achieve at most a loss of 0.15 grades of schooling. We divided this loss by number of years of schooling (10 years, from 5 to 15 years of age) so that children infected in multiple years would not accrue more than 0.15 additional grades of schooling in total. This equates to roughly 1 of every 7 children who remain worm-free for their full school life gaining an extra grade of schooling.

We then calculated the difference in total years of schooling lost between the targets hit and counterfactual scenarios, and the potential impact of this on the children's income once they entered the workforce at age 15. We used the most recent estimates of the wage increments associated with an additional year of schooling for our countries of interest from reviews.[57, 58]

To estimate the proportion of children entering the workforce, we utilised labour force participation and unemployment rates in the countries of interest. Rates for rural areas were used to reflect that it is predominantly rural communities who are affected by these diseases. Most recent data on average incomes for our countries were obtained from the ILO. These all pre-dated our base year (2018) so they were inflated to 2018 levels using the methods described in Turner et al. 2019.[60]

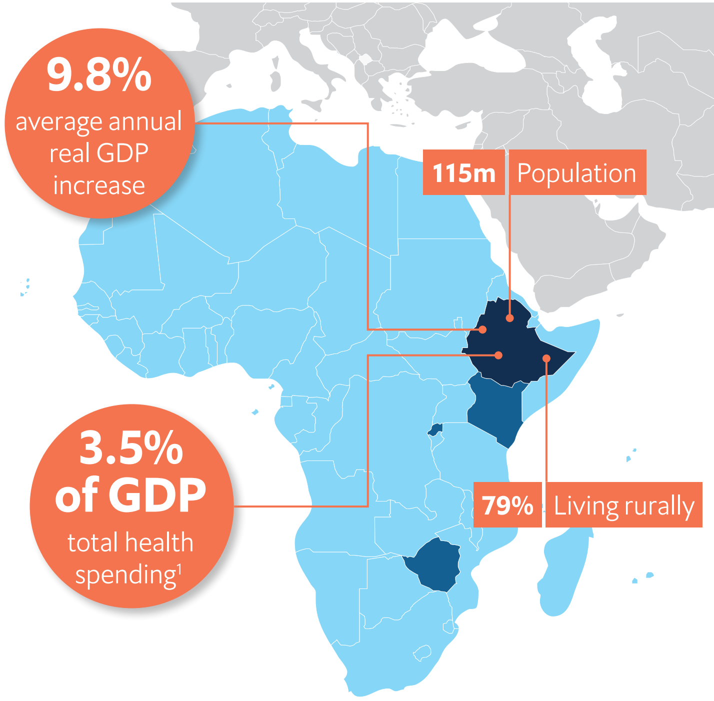
We calculated impact on salaries for the period 2021-2040 only, for comparability with the other estimates for morbidity and mortality. As with GDP, in the base case salaries were assumed to remain at 2018 levels during the term.

Ethiopia Country Profile

Macroeconomic and health-sector background: A growing economy could help the country to overcome remaining challenges

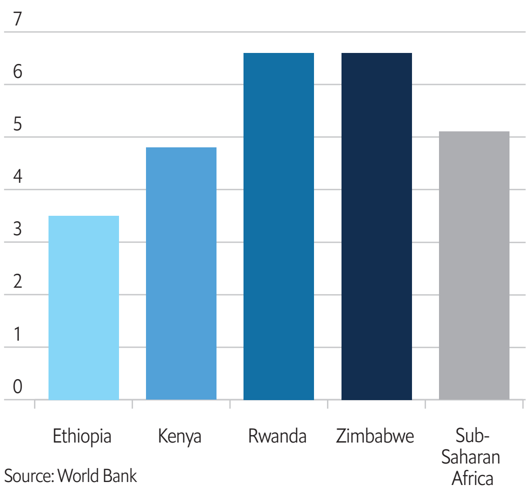
Ethiopia's economy has been one of the fastest growing in the region, expanding by an average of 9.8% annually in real terms over the decade to 2018—an impressive level compared with the sub-Saharan African average of 3.7%.[2] Yet its population remains one of the poorest, with a per capita income of US$735 in 2018. Recent political change has continued to usher in positive economic and social developments, particularly in the health sector.

Although the Economist Intelligence Unit (EIU) forecasts a 2.4% contraction of Ethiopia's GDP in real terms[3] in 2020 as a result of covid-19, a return to growth is predicted in 2021, with GDP forecast to expand by 3.1%.



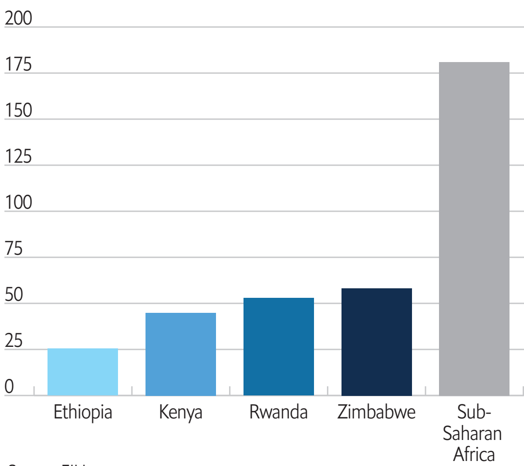
Key health milestones achieved but progress on sanitation mixed

Current health spending as a % of GDP, 2017



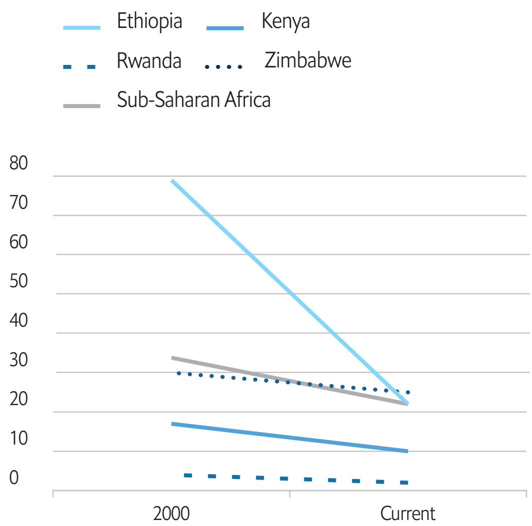
Source: World Bank

Current health spending per capita (Current US$)



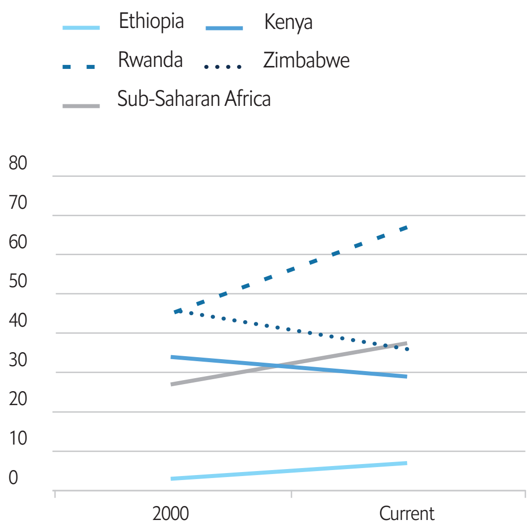
Source: EIU

% of population practising open defaecation



Source: WHO[7]

% of population using at least basic sanitation services



Ethiopia has been hailed as a public health success story, being one of a handful of African countries to have achieved the majority of the Millennium Development Goals in 2015. This is partly attributable to the country's use of long-term health development plans, which have helped to shape a resilient and responsive health system. However, progress on health outcomes has been impeded by the persistence of communicable diseases, including neglected tropical diseases (NTDs).

There has been impressive progress in reducing the percentage of the population practising open defaecation, down from 79% in 2000 to 22% in 2017.[4] However, the percentage of the population with access to at least basic sanitation services was only 7% in 2017, far below the levels in our other countries of interest.[6]

NTD planning in place

Although Ethiopia's recently published Health Sector Transformation Plan categorises NTDs as a priority public health problem, progress towards the World Health Organisation (WHO) 2020 goals for elimination has slowed.[8,9] In line with the national plan, there has been increased domestic investment in combating NTDs, including mapping efforts for various NTDs.[10] The Ministry of Health also

National NTD Plan	Yes – Second Edition of National Neglected Tropical Diseases Master Plan[11]
Timeframe	2015/2016-2019/2020
Includes	✔ Strategic goals ✔ Water, sanitation and hygiene (WASH) interventions ✔ Specified actions needed ✔ Multi-stakeholder support

launched a national deworming programme in 2015. This aimed to treat 80% of at-risk school-age children by 2020. Figures from the WHO suggest that this target was met in 2018.

Soil-transmitted helminthiasis (STH) and schistosomiasis: progress made but still a way to go

18.2m

Requiring preventive chemotherapy for STH in 2018

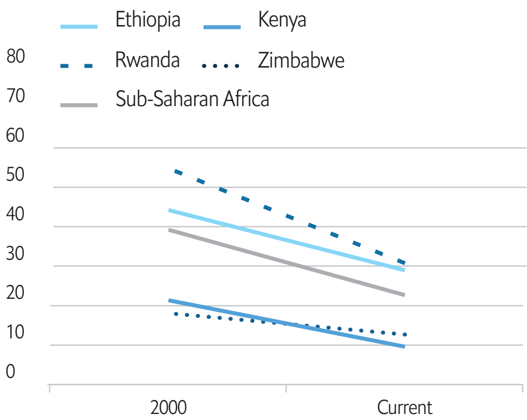
13.4m

Requiring preventive chemotherapy for schistosomiasis in 2018[12]

Schistosomiasis is considered endemic across rural and urban regions in Ethiopia, and the country has the highest rates of the disease among our four countries of interest, with 28% of the population affected.[13] Ethiopia also has the second highest rate of STH, with 29% of the population affected. Within STH, hookworm disease is by far the most common, affecting 25% of the population, while ascariasis and trichuriasis both affect about 3% of the population.

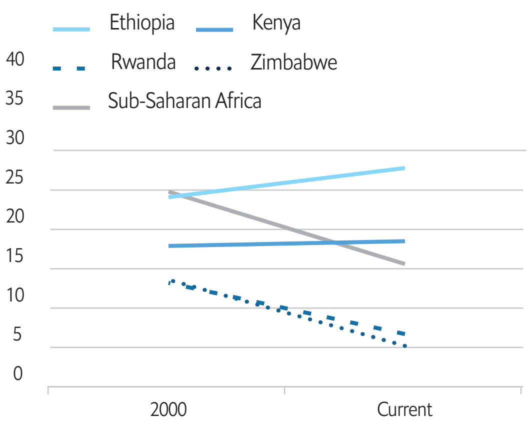
Ethiopia's schistosomiasis prevalence rates climbed from 1990 to around 2010, but have plateaued since then. Despite the increases in prevalence, death rates from schistosomiasis in the period dropped dramatically, decreasing by 91% between 1990 and 2015 (from 6.1 to 0.5 per 100,000).[14] Despite increased mapping and better documentation of the spread of the disease, schistosomiasis infection is still a major cause of morbidity in outpatient cases in large portions of the country.[15] Since 2013 rates of preventive chemotherapy coverage against schistosomiasis have been increasing,

STH prevalence
(age-standardised %)



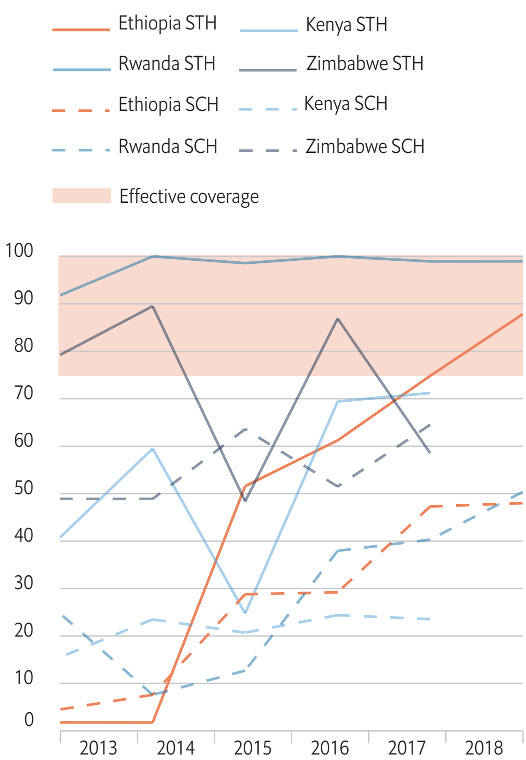
Source: Global Burden of Disease Study 2017

Schistosomiasis prevalence
(age-standardised %)



Source: Global Burden of Disease Study 2017

PCT coverage (%) in our focus countries 2015-2018*



*SCH=PCT coverage for schistosomiasis; STH=PCT coverage for STH.
For STH the graph shows national coverage of school-age children with albendazole.

but they have yet to reach the 75% level required for optimal effectiveness nationally (across both at-risk adults and school-age children in areas affected by the disease). Coverage rates in school-age children are higher than those in adults, reaching almost 89% in 2018.

Progress against STH has been more consistent. Preventive chemotherapy coverage has been increasing, and in 2018 surpassed the 75% target level among school-age children.[16] The prevalence rate dropping steadily from 1990 until about 2010, accompanied by a reduction in the overall loss of healthy life years, and death rates from ascariasis. Worryingly, prevalence rates have recently started to climb slightly, owing to increasing rates of hookworm disease.

Ethiopia faces a challenge if it is to achieve the WHO's 2030 targets. However, the country's growing economy offers the opportunity to reduce poverty, continue the trend for improved sanitation and hygiene, and increase investment in NTD control.

Economic impact of eliminating STH and schistosomiasis

Overall, our calculations suggest that Ethiopia stands to gain US$3.2bn in GDP in purchasing power parity (PPP) terms (US$1bn at market exchange rates) between 2021 and 2040 if the WHO's 2030 elimination targets are hit.[17] To put this in context, this gain is equivalent to over a third (37%) of the country's total spend on health in 2017.

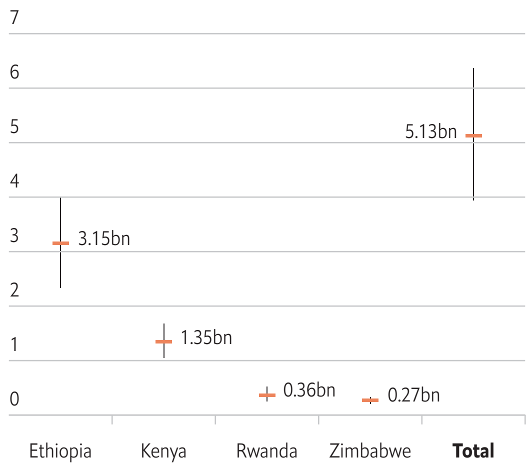
This is the largest gain of any of our four countries of interest, reflecting that the country has the largest number of cases of schistosomiasis and STH (20.6m and 28.6m respectively). The benefit splits almost equally between schistosomiasis and STH, with hookworm disease being the STH with the greatest impact, as it is the most common.

Hitting the WHO 2030 targets would reduce the number of school children affected by these diseases, and the improvement in their health could allow greater educational attainment and wage earning potential. Using estimates from the literature of the possible extent of this educational gain and the link between years of schooling and wages, we modelled this potential gain.

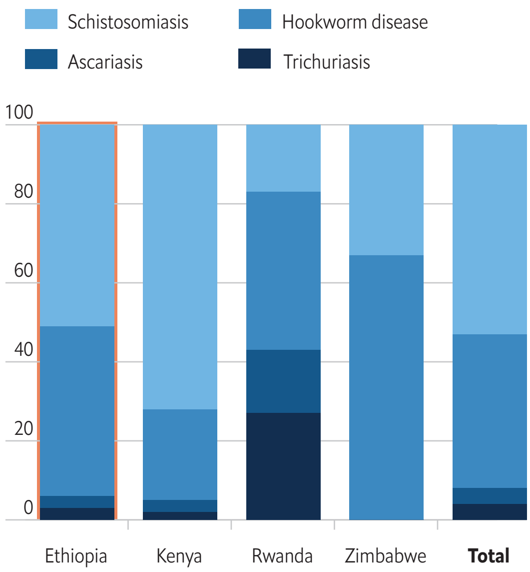
The Economist INTELLIGENCE UNIT

Impact of achieving 2030 WHO targets: GDP gains 2021-40 (US$ billion at PPP)

Horizontal red bars indicate central value, and vertical grey bars indicate upper and lower limits based on uncertainty intervals for prevalence figures from the 2017 Global Burden of Disease study.

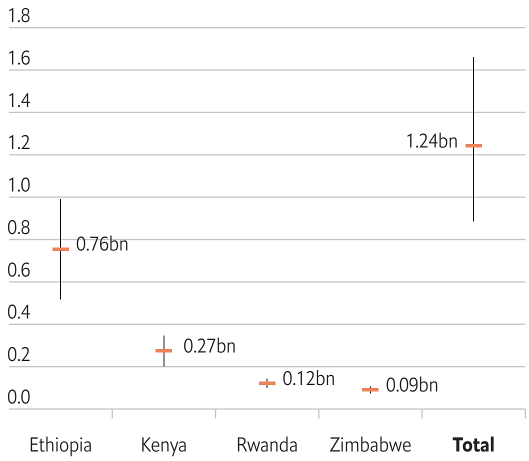


Impact of achieving WHO 2030 targets: Proportion of productivity gains (%) attributable to each disease, 2021-40

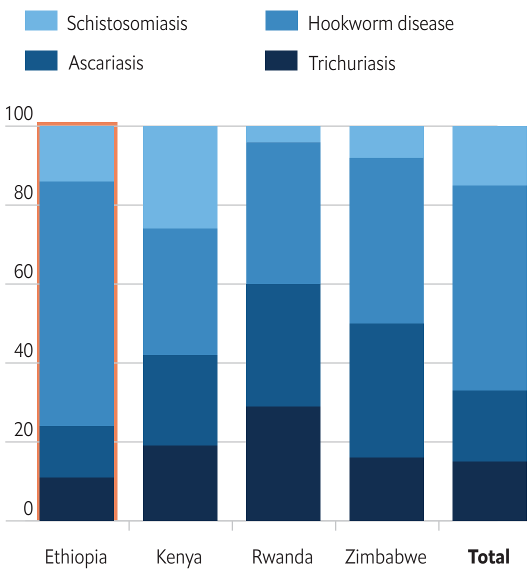


Impact of achieving 2030 WHO targets: Gains in income 2021-40 through better education (US$ billion at PPP)

Horizontal red bars indicate central value, and vertical grey bars indicate upper and lower limits based on uncertainty intervals for prevalence figures from the 2017 Global Burden of Disease study.



Impact of achieving WHO 2030 targets: Proportion of income gains (%) attributable to each disease, 2021-2040



Our analyses suggest that the reduction in these worm infections among school children in Ethiopia between 2021 and 2040 could boost these children's salaries by a total of US$0.8bn at PPP (US$0.3bn at market exchange rates) once they enter the workforce. The majority of this impact would be down to the reduction in hookworm disease, which accounts for just under two-thirds of the benefit seen (62%).

As there is controversy over the extent of any educational benefits arising from deworming, our figures take a conservative approach to potential benefits. For example, we use a conservative estimate of potential benefit from deworming (a maximum of 0.15 grade of schooling gained). Our analyses also use the salaries of the lowest income quintile, to reflect the population affected by these worms, and use a flat rates of future salaries, which is likely to underestimate potential gains in a growing economy like Ethiopia. Similarly conservative assumptions were made for GDP in the productivity loss analyses.

The Way Forward: co-ordinated action for elimination

Despite a relatively high burden, Ethiopia has made progress in reducing the impact of schistosomiasis and STH. Rapid economic growth has been a catalyst to reducing the burden of poverty-related NTDs. Co-ordinated action between the Ministry of Health, implementing partners and donors has led to the improvement of coverage for integrated and effective interventions such as mass drug administration (MDA) and improvements in sanitation. This resulted in an overall reduction in deaths and DALYs from NTDs in Ethiopia between 1990 and 2015.[18] Improved mapping, intensified strategies for testing to assess prevalence and progress towards elimination, and the integration of NTD management in health-worker training has also contributed to this progress.[19]

It is critical that this progress is sustained through expanded treatment coverage and strong monitoring to address the continuous transmission of STH and schistosomiasis in Ethiopia. Continued health loss due to these diseases has the potential to undermine Ethiopia's socioeconomic gains in recent years. Coordination between the health ministry, the NTD programme and other health programmes and sectors is critical if the country is to reach the WHO's goals for control and elimination of parasitic worms.

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13. Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2017 (GBD 2017) results [Internet]. Seattle [WA]: Institute of Health Metrics and Evaluation; [cited 13 July 2020]. Available from: http://ghdx.healthdata.org/gbd-results-tool.

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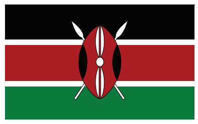
Kenya Country Profile

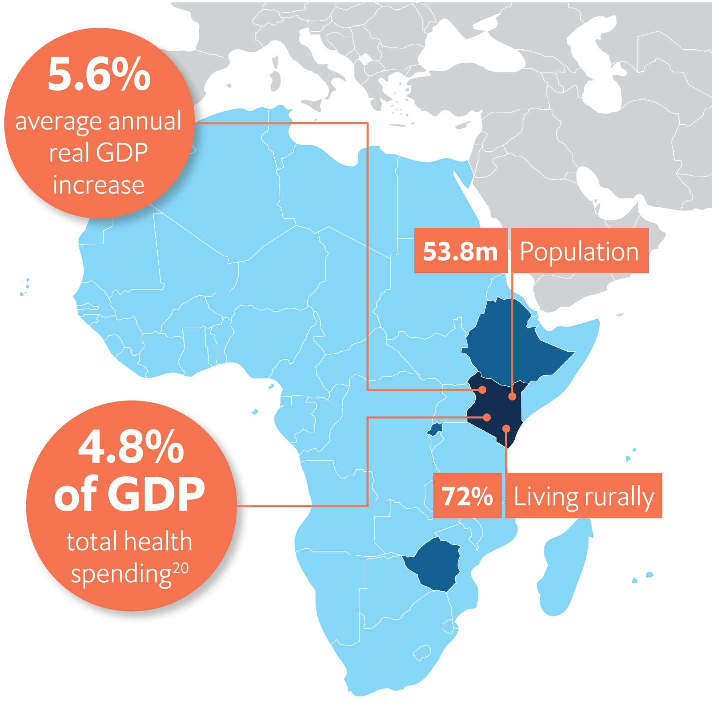


Macroeconomic and health-sector background: Sustained economic growth and social development

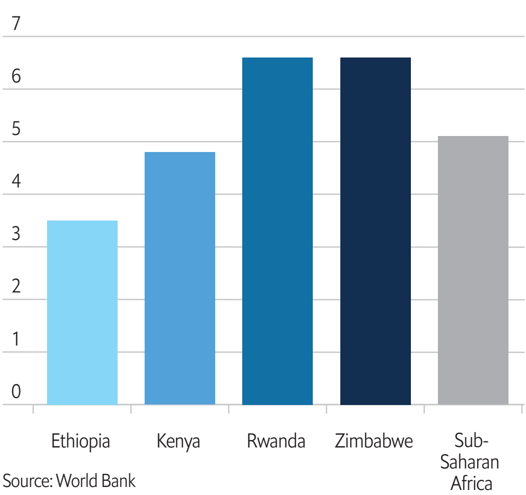
Kenya is an exemplar of sustained economic growth and social development, even while its political landscape continues to undergo periodic instability and reform. The country's economy grew by about 5.6% annually in real terms in the decade to 2018.[21,22] This is higher than the overall 3.7% growth seen in sub-Saharan Africa over the same period. Kenya's GDP per capita is among the highest of our four countries, at US$1,708 in 2018, ranking it as a lower-middle income country.

The Economist Intelligence Unit forecasts a contraction of Kenya's GDP in real terms of 2.5% in 2020 as a result of covid-19, followed by a return to growth in 2021, at 2%.

Social development has been most visible in increased spending on education (focused on achieving universal primary school enrolment) and health (reduced child mortality, free

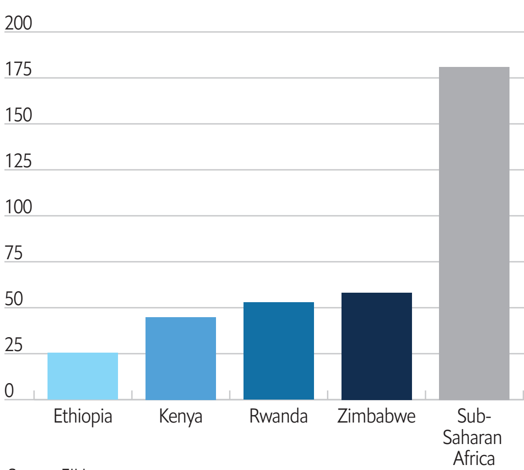


Current health spending as a % of GDP, 2017



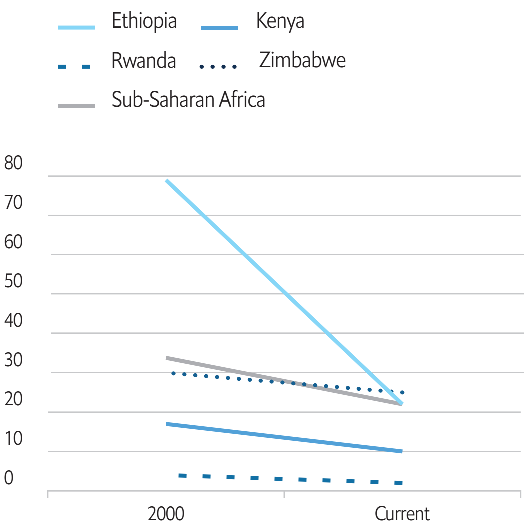
Source: World Bank

Current health spending per capita (Current US$)



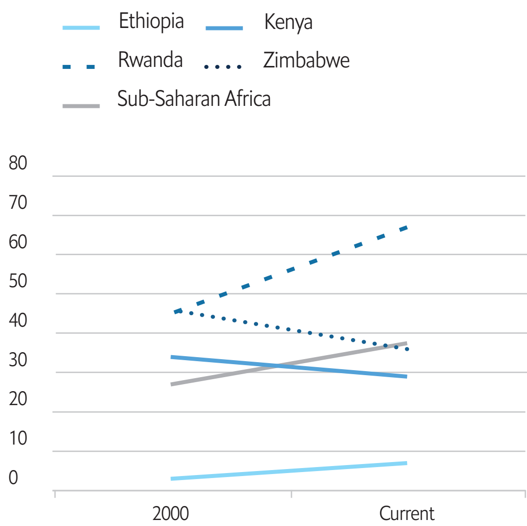
Source: EIU

% of population practising open defaecation



Source: WHO[27]

% of population using at least basic sanitation services



maternal health care). Changes to the Kenyan constitution in 2010 entailed the devolution of governance mechanisms, including health functions.[23]

There has been impressive progress in reducing the percentage of the population practising open defaecation, down from 17% in 2000 to 10% in 2017.[24] The percentage of the population with access to at least basic sanitation services[25] has fallen, from 34% in 2000 to 29% in 2017.[26]

Kenya's national NTD programme defines policy direction, while counties implement control and elimination activities. In 2016 the Ministry of Health articulated a Multi-Year Strategic Plan of Action for the control of NTDs, following the publication of a similar plan in 2011.[28]

Kenya has supported mapping and deworming exercises at scale since 2012. Since then, 19 Kenyan counties have conducted mapping exercises for soil-transmitted helminthiasis (STH) and schistosomiasis. This was supplemented by the launch of a 5-year National School-Based Deworming Programme (NSBDP) in 2012. Through the programme at least 6m children received preventive chemotherapy for STH and schistosomiasis annually.[29, 30] The most recent data from the WHO estimates that in 2017

National NTD Plan	Yes - The 2nd Kenya National Strategic Plan for control of Neglected Tropical Diseases (NTDs)
Timeframe	2016-2020
Includes	✔ Strategic goals ✔ Water, sanitation and hygiene (WASH) interventions ✔ Specific actions to take ✔ Multi-stakeholder support

national preventive chemotherapy coverage for school-age children in Kenya was 71% for STH and 41% for schistosomiasis (coverage rates are lower if preschool-age children and adults are included).[31]

STH and schistosomiasis: Uneven progress through school-based deworming

9.2m

Requiring preventive chemotherapy for STH in 2018

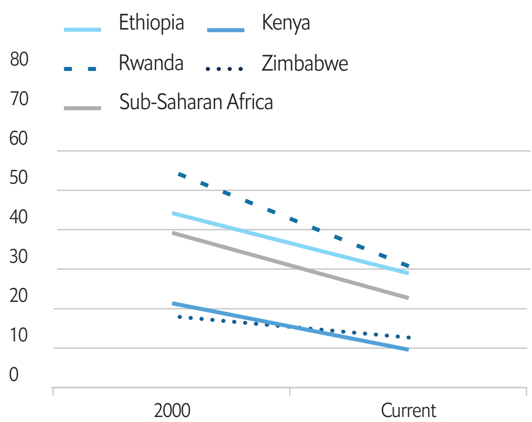
2.8m

Requiring preventive chemotherapy for schistosomiasis in 2018[32]

Soil-transmitted helminths are endemic in the southern coastal and western regions of Kenya. According to a baseline survey conducted by the Kenya Medical Research Institute (KEMRI) at the start of the deworming programme in 2012, 32.3% of school-age children were infected. The programme reduced infection rates in children by an impressive 58.2% by 2017.[33] This reduction has been mirrored by an overall 56% reduction in the prevalence rate of STH infections in Kenya between 2000 and 2017.[34] STH rates in Kenya are the lowest of any of our four countries, with only 9.6% (4.7m) of the population affected, well below the rates for sub-Saharan Africa as a whole.

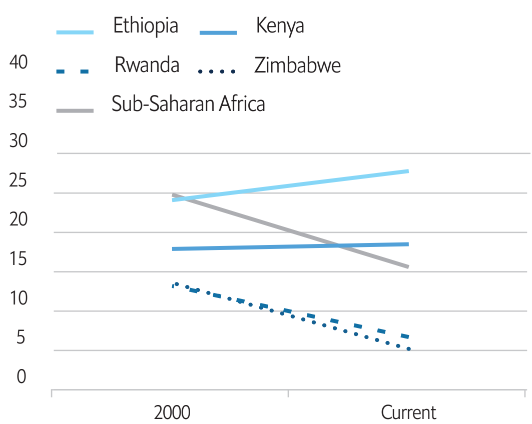
The highest prevalence of schistosomiasis is in areas with irrigation systems and in the lake regions in the lower-eastern part of the country. The KEMRI survey found that

STH prevalence
(age-standardised %)



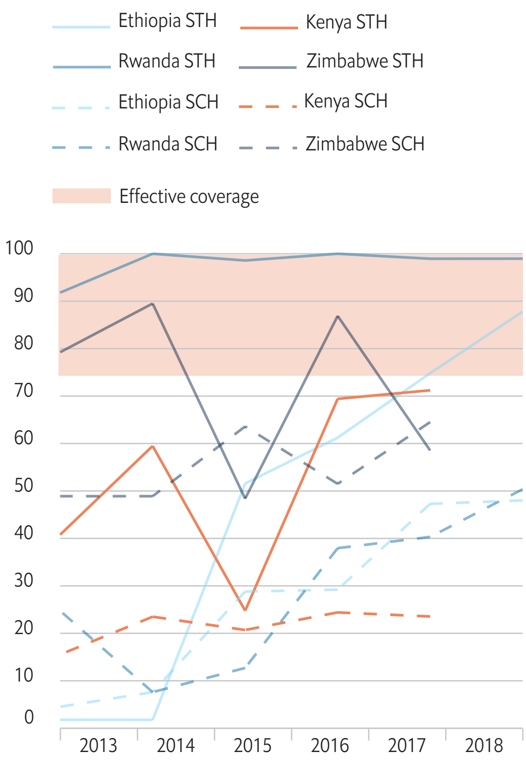
Source: Global Burden of Disease Study 2017

Schistosomiasis prevalence
(age-standardised %)



Source: Global Burden of Disease Study 2017

PCT coverage (%) in our focus countries 2015-2018*



*SCH=PCT coverage for schistosomiasis; STH=PCT coverage for STH.
For STH the graph shows national coverage of school-age children with albendazole.

schistosomiasis reduced by 59.3% among school-age children between 2012 and 2017. Despite this, the age-standardised schistosomiasis prevalence in the country has crept up, with 18.5% (7.1m) of the population affected.

This rise in prevalence is likely to reflect that preventive chemotherapy coverage among at risk groups for schistosomiasis is lower than for STH (24% versus 71% in 2017).[35,36] In 2017 5.6% of the 123m total schistosomiasis infections in sub-Saharan Africa occurred in Kenya. [37]

Achieving the WHO's 2030 target for STH seems within reach for Kenya, but doing so for schistosomiasis may be more difficult.

Economic benefit of eliminating STH and schistosomiasis

Overall, Kenya stands to gain US$1.3bn in GDP in purchasing power parity (PPP) terms (US$0.5bn at market exchange rates) between 2021 and 2040 if the WHO's 2030 elimination targets are hit.[38] To put this in context, this is equivalent to 13% of the country's total spend on health in 2017.

This is the second largest gain of any of our four countries of interest, reflecting the fact that the country has the second-largest number of cases of schistosomiasis and STH (7.1m and 4.7m respectively). Elimination of schistosomiasis accounts for 72% of the potential gains, and hookworm disease (the most common STH) 23%.

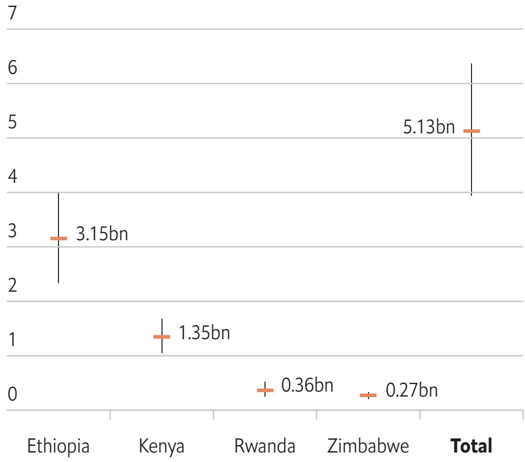
Our base-case figures use flat rates of future GDP, which will underestimate gains in a growing economy like Kenya. Using our long-term GDP forecast[39] almost doubles the benefits from hitting the WHO targets, increasing estimated gains to US$2.5bn (PPP).

Hitting the WHO 2030 targets would reduce the number of school children affected by these diseases, and the improvement in their health could allow greater educational attainment and wage earning potential. Using estimates from the literature of the possible extent of this educational gain and the link between years of schooling and wages, we modelled this potential gain.

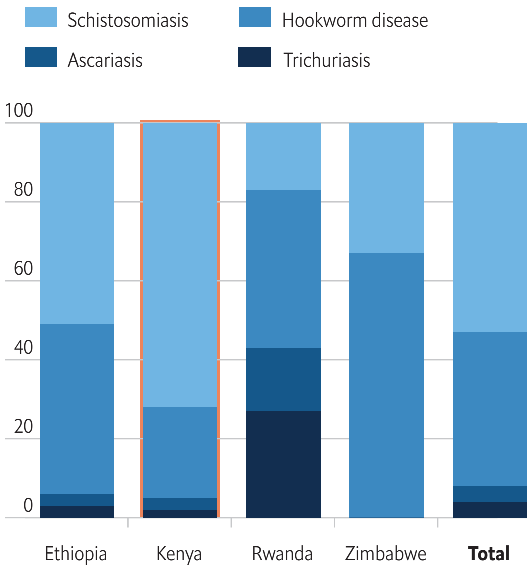
Our analyses suggest that the reduction in these worm infections among school children

Impact of achieving 2030 WHO targets: GDP gains 2021-40 (US$ billion at PPP)

Horizontal red bars indicate central value, and vertical grey bars indicate upper and lower limits based on uncertainty intervals for prevalence figures from the 2017 Global Burden of Disease study.

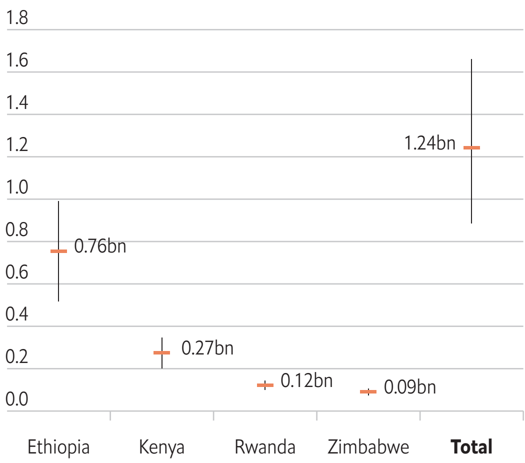


Impact of achieving WHO 2030 targets: Proportion of productivity gains (%) attributable to each disease, 2021-40

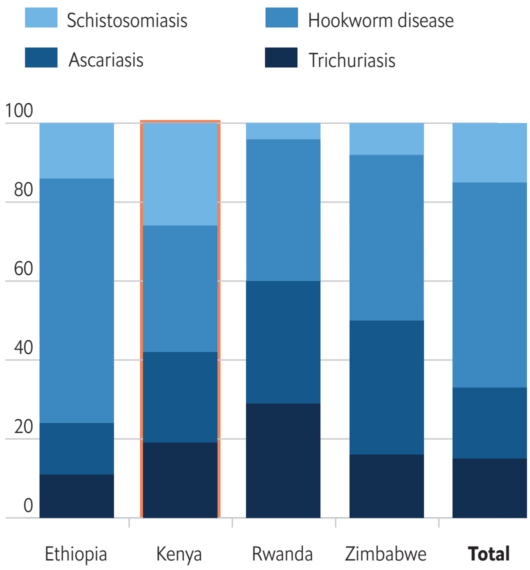


Impact of achieving 2030 WHO targets: Gains in income 2021-40 through better education (US$ billion at PPP)

Horizontal red bars indicate central value, and vertical grey bars indicate upper and lower limits based on uncertainty intervals for prevalence figures from the 2017 Global Burden of Disease study.



Impact of achieving WHO 2030 targets: Proportion of income gains (%) attributable to each disease, 2021-2040



in Kenya between 2021 and 2040 could boost these children's salaries by a total of US$0.3bn at PPP (US$0.1bn at market exchange rates) once they enter the workforce. The majority of this impact would be due to a reduction in STH, with 32% due to a reduction of hookworm disease, 23% to ascariasis and 19% to trichuriasis. Elimination of schistosomiasis accounts for 26% of the gains, a higher proportion than for any of the other countries.

As there is controversy over the extent of any educational benefits arising from deworming, our figures take a conservative approach to potential benefits. For example, we use a conservative estimate of potential benefit from deworming (a maximum of 0.15 grade of schooling gained). Our analyses also use the salaries of the lowest income quintile, to reflect the population affected by these worms, and use a flat rates of future salaries, which is likely to underestimate potential gains in a growing economy like Kenya.

Investing in eliminating parasitic worms aligns with Kenya's focus on improving education and health, and can provide economic benefits. More work is needed in improving sanitation, where standards have fallen.

The way forward: Expanded coverage and complementarity for elimination

Although the national school-based deworming programme has achieved great success, there are concerns that it has not been fully integrated into Kenya's devolved health structure. This has implications for efforts to develop community-wide deworming initiatives and reach other at-risk groups, such as women of reproductive age, preschool-age children and children who are unable to attend school. This decentralised response structure could also pose an issue in regard to the extent of the availability of community-based prevalence data at a national level to inform planning.

Many studies have cited the inability of mass deworming programmes alone to break transmission cycles in Kenya.[40,41] As such, Kenya's school-focused deworming programme must both expand treatment coverage and incorporate complementary hygiene-based and behaviour-change strategies. To this end, the Ministry of Health established an inter-agency committee on NTDs in 2016.[42] Kenya's subnational implementation has the potential to leverage strengthened linkages between communities and health systems to provide the locally tailored strategies that will be needed to achieve control and elimination of parasitic worms.

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21. Real GDP removes the impact of inflation, so gives a measure of true change of a country's productivity and allows a more meaningful comparison of growth year on year.

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24. WHO. The Global Health Observatory [Internet]. Geneva: World Health Organization. Available from: https://www.who.int/data/gho.

25. Basic sanitation services are defined as improved sanitation facilities not shared with other households. Improved sanitation facilities are designed to separate human waste from human contact, and include flush/pour toilets connected to piper sewer systems, septic tanks or pit latrines, also pit latrines with cleanable cover slabs or ventilated pit latrines, and composting toilets

26. WHO. The Global Health Observatory [Internet]. Geneva: World Health Organization. Available from: https://www.who.int/data/gho.

27. Most recent data available is for 2017.

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35. WHO. Preventive Chemotherapy (PC) Data Portal [Internet]. Geneva: World Health Organization. Available from: http://apps.who.int/gho/cabinet/pc.jsp.

36. National PCT coverage is calculated as the % of individuals judged to be at risk who receive PCT. For schistosomiasis both adults and school-age children in endemic areas are included in the denominator as they are recommended to receive treatment. For STH only school-age children in endemic areas included in the denominator, as not all adults in endemic areas are recommended to receive PCT. Preschool children are also recommended to receive PCT for schistosomiasis and STH, but there is no drug formulation licensed for treating the former in this age group. PCT coverage of preschool children for STH is lower than that for school-age children.

37. Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2017 (GBD 2017) results [Internet]. Seattle [WA]: Institute of Health Metrics and Evaluation; [cited 13 July 2020]. Available from: http://ghdx.healthdata.org/gbd-results-tool.

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40. Jia T-W, Melville S, Utzinger J, et al. Soil-transmitted helminth reinfection after drug treatment: a systematic review and meta-analysis. PLoS Neglected Tropical Diseases. 2012;6(5):e1621.

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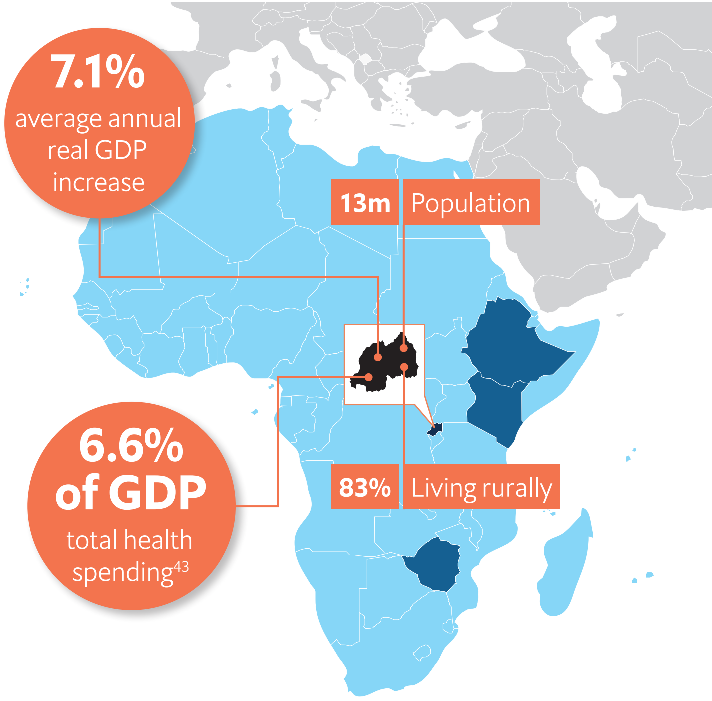
42. Matendechero SH. Drugs for neglected diseases presentation, 2017. Nairobi: Republic of Kenya Ministry of Health, 2017. Available from: https://www.dndi.org/wp-content/uploads/2017/02/Dr_Sultani_ASTMH-in-Kenya_presentation.pdf.

Rwanda Country Profile

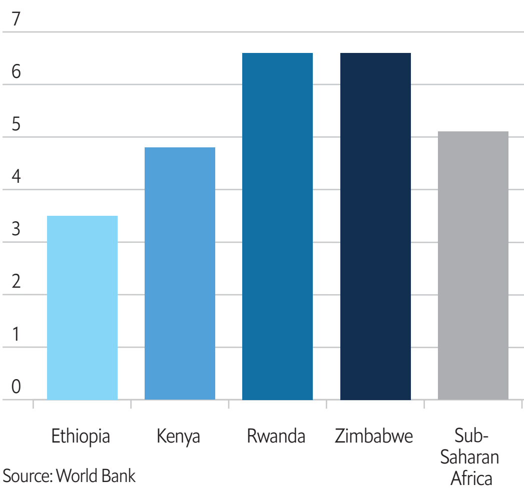
Macroeconomic and health-sector background: A youthful, rapidly developing country

Rwanda is the most densely populated country in sub-Saharan Africa.[44] It is a young country, with over half of Rwandans under the age of 20 years.[45] In the decade to 2018, Rwanda experienced significant economic growth and socioeconomic progress, an especially salient fact given its unstable political situation before 1994. Against a sub-Saharan average of 3.7% over the same period, Rwanda's economic growth rates have averaged 7.1% annually in real terms.[46] The Economist Intelligence Unit's economic forecast for Rwanda predicts a slowing of growth to 2.3% in 2020, taking into account the impact of covid-19.

Rwanda's impressive economic growth has been accompanied by substantial improvements in living standards and overall poverty reduction. Poverty declined by 20% between 2001 and 2014 (from 59% to 39%), although it has remained relatively static since.

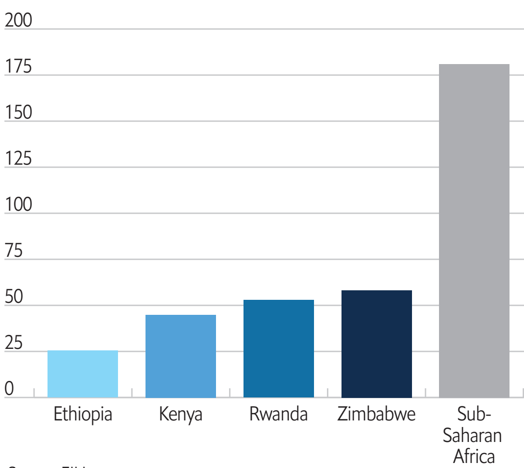


Current health spending as a % of GDP, 2017



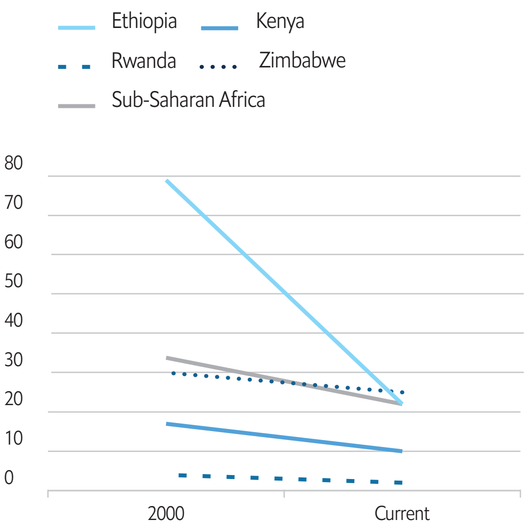
Source: World Bank

Current health spending per capita (Current US$)



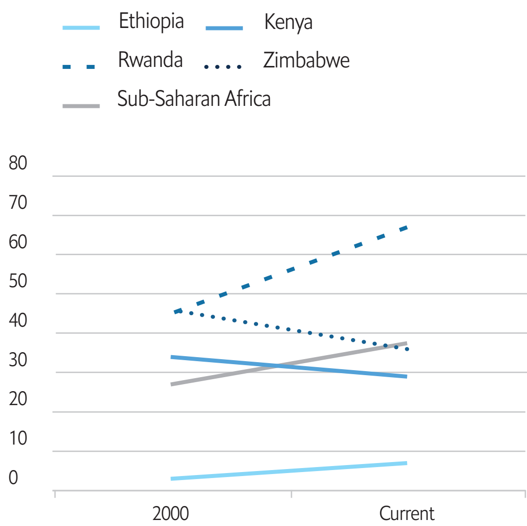
Source: EIU

% of population practising open defaecation



Source: WHO[53]

% of population using at least basic sanitation services



Inequality has also declined since 2006. When compared with the continental poverty decline rate of 10% over the same period, Rwanda's progress is remarkable.[47] Rwanda's social development achievements have addressed some of the main components of the Millennium Development Goals; for example, its child mortality rate has reduced by almost two-thirds and primary school enrolment is near universal.[48]

The percentage of the population practising open defaecation halved from 4% in 2000 to 2% in 2017, the lowest rate of any of our four countries.[49] The percentage of the population with access to at least basic sanitation services[50] has also risen substantially, from 45% in 2000 to 67% in 2017.[51] These successes contribute to population health improvements, including a reduction in parasitic worm infections.

Based on its national vision of home-grown policies and initiatives, the Rwandan health sector has established governance structures at central and local levels. In addition, community engagement is actively promoted in the current national strategic plan on neglected tropical diseases (NTDs), in order to increase communities' involvement in and accountability for their own health. Addressing health challenges and the social determinants of health remain a top national priority.[52]

National NTD Plan	Yes – Neglected Tropical Diseases Strategic Plan
Timeframe	2019-2024
Includes	✔ Strategic goals ✔ Water, sanitation and hygiene (WASH) interventions ✔ Specific actions to take ✔ Multi-stakeholder support

Soil-transmitted helminthiasis (STH) and schistosomiasis: Rates nearly halved since 2000

4.5m

Requiring preventive chemotherapy for STH in 2018

2.6m

Requiring preventive chemotherapy for schistosomiasis in 2018[54]

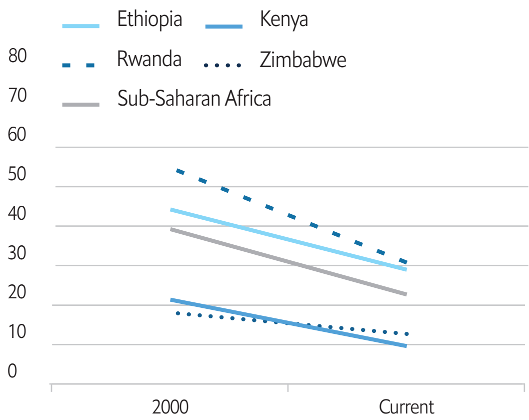
NTDs remain an obstacle to the socioeconomic development and quality of life of the people of Rwanda.[55] *Schistosoma mansoni* (which causes intestinal but not genitourinary schistosomiasis) and all the major species of STH are endemic in Rwanda.

Prior to 2010, despite increasing recognition of the importance of NTDs, funding at the national level was limited. Between 2007 and 2010, US$3.3m in philanthropic funding was provided to support the Ministry of Health's NTD programme.[56]

This funding enabled a wider variety of activities, including assessing the distribution of NTDs through country-wide mapping.[57] In June 2007 the Ministry of Health also launched a large-scale control programme for NTDs, targeting the five NTDs for which preventive chemotherapy is available.

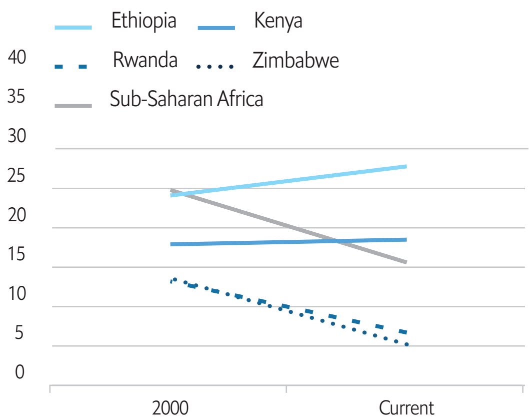
The funding also covered diagnostic equipment for health facilities, health personnel training and the development of indicators that were added to the country's Health Management Information System. These investments laid the foundation for continued treatment and control, as well as developing the long-term capacities of the national health system.[58]

STH prevalence
(age-standardised %)



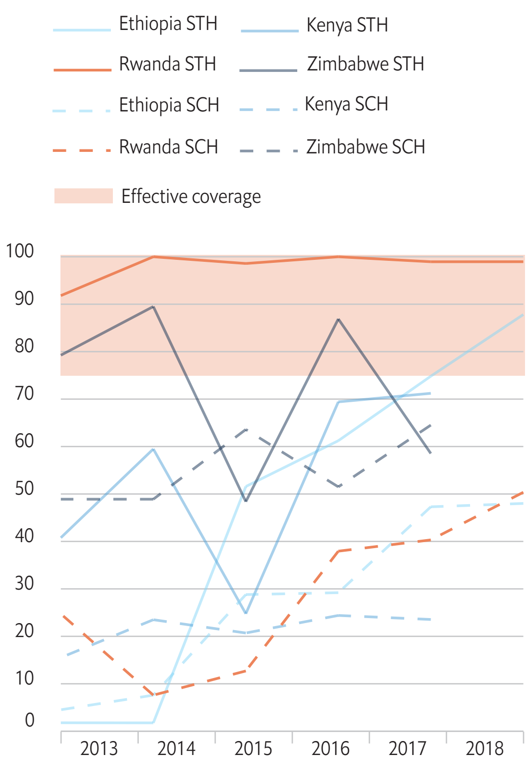
Source: Global Burden of Disease Study 2017

Schistosomiasis prevalence
(age-standardised %)



Source: Global Burden of Disease Study 2017

PCT coverage (%) in our focus countries 2015-2018*



*SCH=PCT coverage for schistosomiasis; STH=PCT coverage for STH.
For STH the graph shows national coverage of school-age children with albendazole.

Mass drug administration (MDA) was also integrated within maternal-child health weeks, and in 2008 adults living in areas with a high prevalence of schistosomiasis were included in the MDA programme.[59]

As a result of these efforts, prevalence rates of both schistosomiasis and STH almost halved in Rwanda between 2000 and 2017, respectively falling from 13% to 6.7% and 55% to 31%.[60]

However, despite the high rate of preventive chemotherapy against STH and their reduction in prevalence, the rate is still the highest among our four countries, and 3.8m of Rwanda's population were affected in 2017. The number affected by schistosomiasis was much lower (0.7m).

In its NTD Strategic Plan, Rwanda has set itself the ambitious targets of eliminating schistosomiasis as a public health problem (national prevalence below 0.5%) and achieving a national STH prevalence rate of below 20%.[61] The need for sustained treatment of at-risk adults is acknowledged in this strategy, which includes a target of treating 97% of adults in STH- and schistosomiasis-endemic districts. In addition, in 2018 more than 42,000 community health workers were trained in the prevention of common NTDs.

Economic benefit of eliminating STH and schistosomiasis

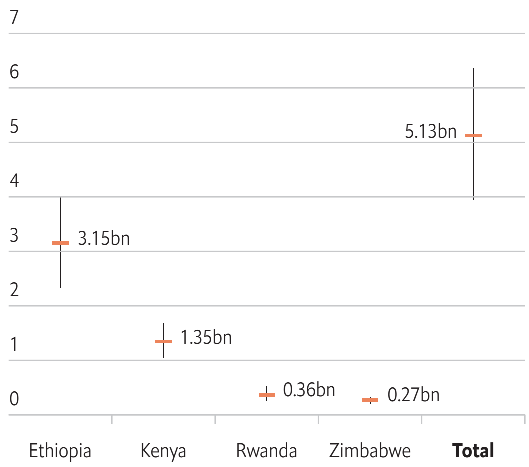
Overall, Rwanda stands to gain US$0.4bn in GDP in purchasing power parity (PPP) terms (US$0.1bn at market exchange rates) between 2021 and 2040 if the WHO's 2030 elimination targets are hit.[62] To put this into context this equates to almost a quarter (22%) of the country's overall spend on health in 2017. Total losses are smaller for Rwanda than the other countries owing to its smaller population and economy.

The high rates of STH in Rwanda mean that their elimination would account for the majority of the gains (83%), with hookworm disease accounting for the largest proportion (40%), followed by trichuriasis (27%) and ascariasis (16%). Elimination of schistosomiasis would account for 17%.

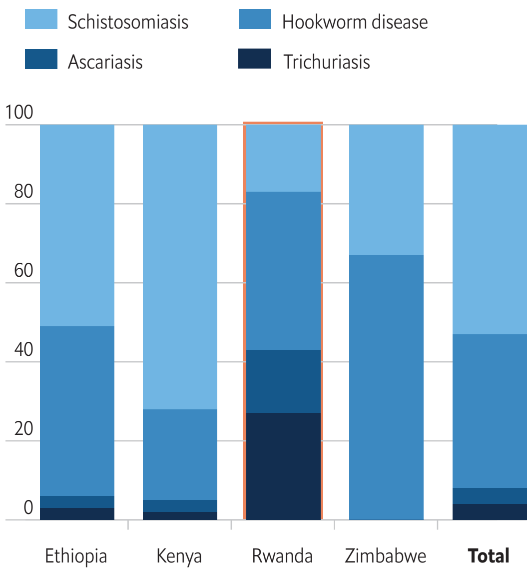
Our base-case figures use flat rates of future GDP, which may underestimate gains in a growing economy like Rwanda.

Impact of achieving 2030 WHO targets: GDP gains 2021-40 (US$ billion at PPP)

Horizontal red bars indicate central value, and vertical grey bars indicate upper and lower limits based on uncertainty intervals for prevalence figures from the 2017 Global Burden of Disease study.

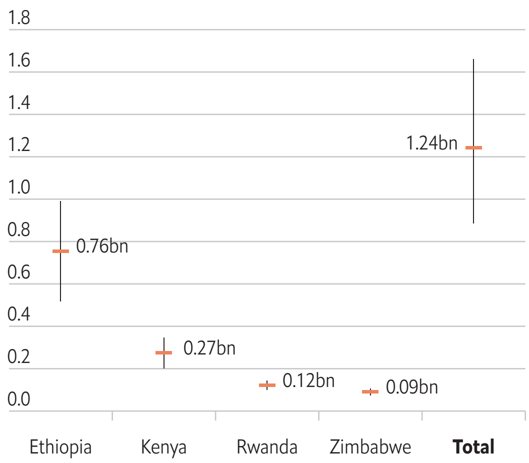


Impact of achieving WHO 2030 targets: Proportion of productivity gains (%) attributable to each disease, 2021-40

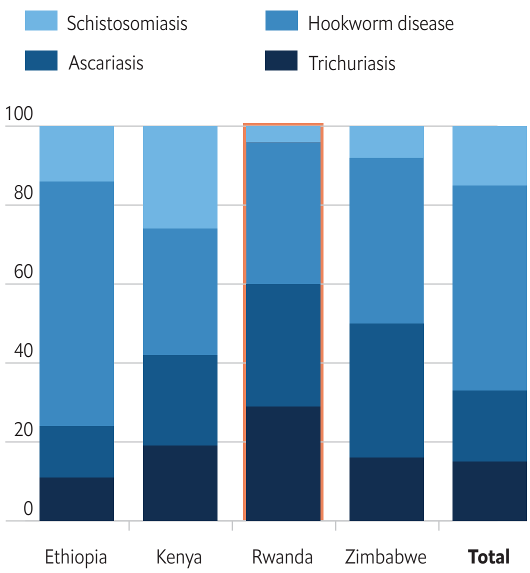


Impact of achieving 2030 WHO targets: Gains in income 2021-40 through better education (US$ billion at PPP)

Horizontal red bars indicate central value, and vertical grey bars indicate upper and lower limits based on uncertainty intervals for prevalence figures from the 2017 Global Burden of Disease study.



Impact of achieving WHO 2030 targets: Proportion of income gains (%) attributable to each disease, 2021-2040



Hitting the WHO 2030 targets would reduce the number of school children affected by these diseases, and the improvement in their health could allow greater educational attainment and wage earning potential. Using estimates from the literature of the possible extent of this educational gain and the link between years of schooling and wages, we modelled this potential gain.

Our analyses suggest that the reduction in these worm infections among school children in Rwanda between 2021 and 2040 could boost their salaries by a total of US$0.1bn at PPP (US$0.04bn at market exchange rates) once they enter the workforce. These numbers are the smallest of our countries; again, this is due to the smaller size of the population and economy in Rwanda.

The vast majority (96%) of the impact of education-related gains would be down to the reduction in STH, with 35% down to hookworm disease, 31% to ascariasis and 29% to trichuriasis. The elimination of schistosomiasis only accounts for 4% of the gains, reflecting its lower prevalence among school-age children.

As there is controversy over the extent of any educational benefits arising from deworming, our figures take a conservative approach. For example, we use a conservative estimate of potential benefit from deworming (a maximum of 0.15 grade of schooling gained). Our analyses also use the salaries of the lowest income quintile, to reflect the population affected by these worms, and use a flat rates of future salaries, which is likely to underestimate potential gains in a growing economy like Rwanda. Similarly conservative assumptions were made for GDP in the productivity loss analyses.

Rwanda has shown impressive progress in reducing its rates of both schistosomiasis and STH. It has set itself an ambitious target of achieving schistosomiasis elimination in 2024, well ahead of the WHO's 2030 target. While hitting this ambitious target could be within reach for schistosomiasis, it will require more effort for STH. Rwanda's strong investment in its health system and impressive achievements in reducing poverty and inequality, as well as improving sanitation and hygiene, suggest that the country will be able to rise to the challenge.

The way forward: Integrated programmes are essential

Rwanda's strong emphasis on a community intervention approach has yielded a resilient NTD programme. A key achievement is the reduction of lymphatic filariasis, onchocerciasis and trachoma prevalence to below the threshold requiring MDA programmes. The countrywide MDA programme has also resulted in decreased prevalence and intensity of STH and schistosomiasis.

Despite these successes, broader challenges in hygiene and sanitation, as well as the impact of climate change, mean that transmission continues in the country's most endemic districts, resulting in re-infection of the treated population.[63,64] Achieving sustainability for the Rwandan NTD programme and attaining the goals of control and elimination of these diseases necessitates an intensified and more integrated approach that involves other ministries, such as those responsible for water and sanitation. The country has made steps towards this, with the most recent NTD plan laying out a clear multi-stakeholder framework of activities required to achieve its goals for 2024.[65]

In addition, technical and financial support from donors and international stakeholders should be supplemented by financial commitments from the Ministry of Health and other relevant ministries to sustain the response to parasitic worm infections in the country, particularly as external funding has been noted to be on a decline.[66] The Ministry of Health has committed to mobilise resources for NTDs through development partners and health-sector funding mechanisms.[67]

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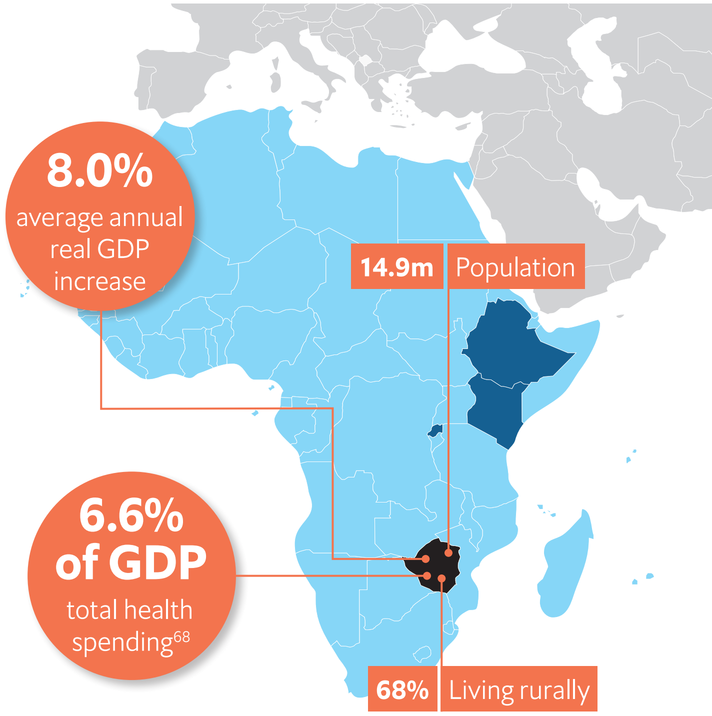
Zimbabwe Country Profile

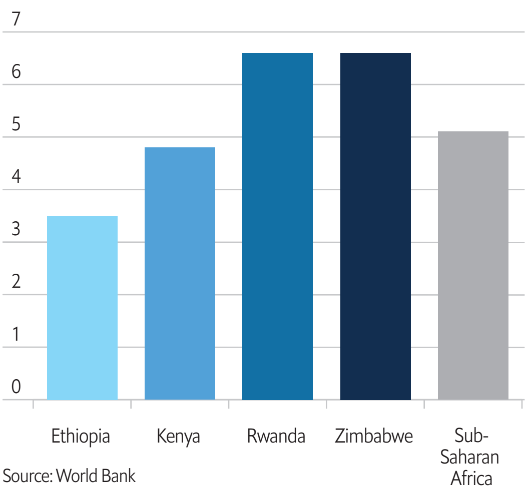
Macroeconomic and health-sector background: A tumultuous decline

Zimbabwe's development over the past two decades has been defined by political turmoil coupled with dramatic climate change. Corruption and mismanagement of government resources has seriously impacted the economy, as well as the once-thriving health system. This has been compounded by a prolonged drought, which has limited the ability of farmers to grow crops commercially. As the agriculture sector employs nearly two-thirds of the workforce, this has slowed economic recovery.[69] The amount of people in extreme poverty in the country rose by nearly 1m from 2018 to 2019, with the prices of basic commodities rising sharply.[70]

Health-sector funding has been cut in recent years, leaving the nation struggling to meet the most basic health and social needs of its citizens. Zimbabwe's health expenditure as a percent of GDP is approximately 6.6%, which

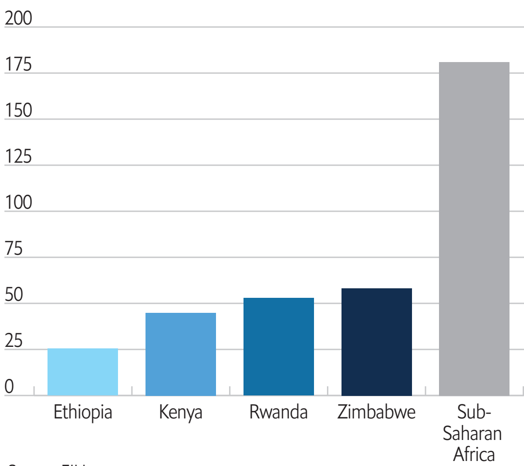


Current health spending as a % of GDP, 2017



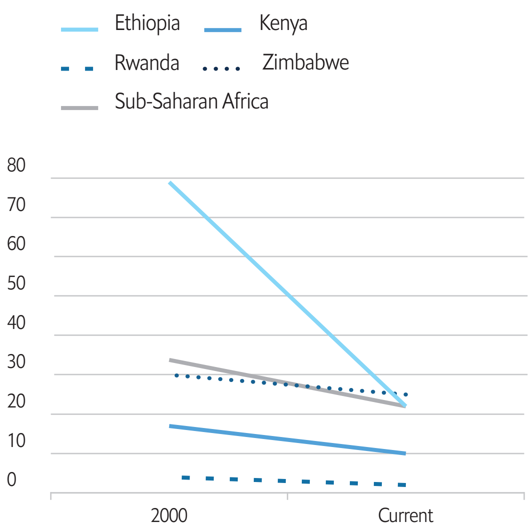
Source: World Bank

Current health spending per capita (Current US$)



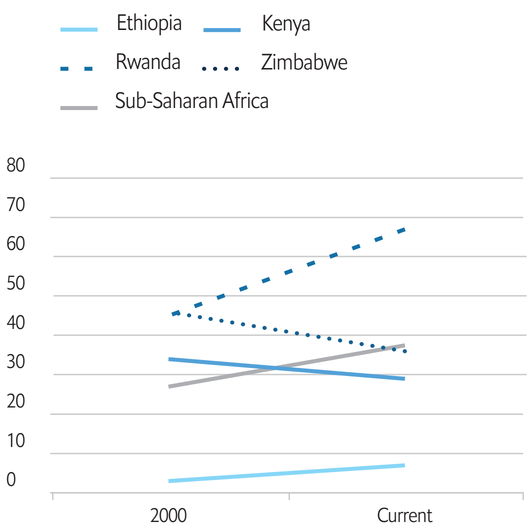
Source: EIU

% of population practising open defaecation



Source: WHO[78]

% of population using at least basic sanitation services



surpasses the sub-Saharan Africa average of 5.2%.[71] The government will need to continue investing in the health system, as international organisations and foreign governments have been reluctant to invest in Zimbabwe for decades. The dire economic conditions in Zimbabwe have left a gap in access to healthcare whereby neither households nor the government can afford to fund health services adequately.[72]

Despite its challenging social and economic context, Zimbabwe has achieved progress in reducing the percentage of the population practising open defaecation, from 30% in 2000 to 25% in 2017.[73] However, the percentage of the population with access to at least basic sanitation[74] has also fallen, dropping from 46% in 2000 to 36% in 2017.[75] This reflects in part the lack of investment and capacity in the sanitation sector as a result of Zimbabwe's economic plight.[76] This reduction in access to basic hygiene may adversely affect progress towards elimination and control of parasitic worm infection.

Though funding has not always been secure, Zimbabwe has shown that long-term health planning is a government priority. The National Health Strategy 2016-2020 lays out specific

National NTD Plan	• Not publicly available • NTD control mentioned in national health strategy
Timeframe	2016-2020
Includes	✔ Strategic goals (one broad goal for STH and schistosomiasis) ✔ Water, sanitation and hygiene (WASH) interventions (included but not in the context of NTDs) ✔ Specific actions to take (included but are not measurable) ✘ Multi-stakeholder support

objectives to improve population health as well as move towards Sustainable Development Goal 3 (Ensure healthy lives and promote well-being for all at all ages).[77]

At the time of publishing Zimbabwe's neglected tropical disease (NTD) plan was not publicly available.

Soil-transmitted helminthiasis (STH) and schistosomiasis: Steady progress but an uncertain future

5.8m

Requiring preventive chemotherapy for STH in 2018

3.8m

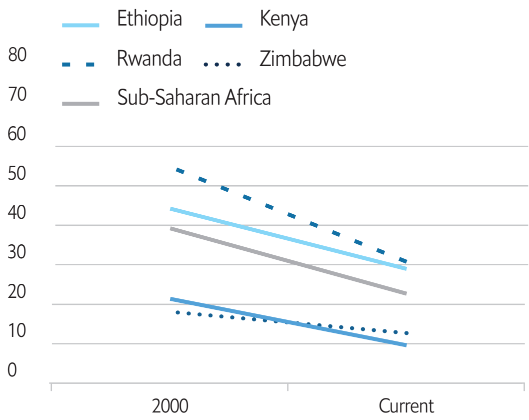
Requiring preventive chemotherapy for schistosomiasis in 2018[79]

Four NTDs that are treatable through preventive chemotherapy are known to be endemic in Zimbabwe: schistosomiasis, STH, lymphatic filariasis and trachoma.[80] The status of other NTDs is unclear, as mapping has not been completed for all NTDs.[81]

The 2009-2013 National Health Strategy noted that progress on schistosomiasis had been slow owing to drug costs and more deadly diseases and natural disasters taking priority.[82] This was despite schistosomiasis increasing in prevalence and being one of the top-ten causes of hospital consultations in Zimbabwe at the time. The strategy mandated a national survey of schistosomiasis as one of its top-ten areas of focus, highlighting the government's interest in understanding the distribution and burden of the disease.[83]

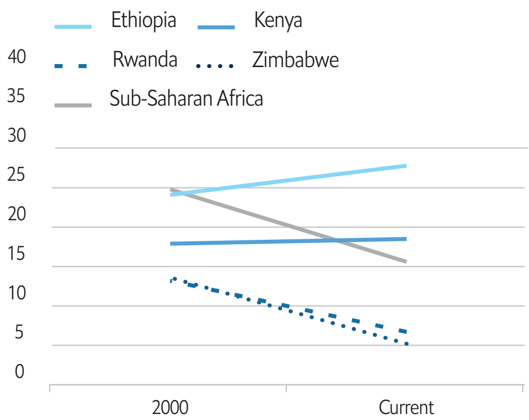
The resulting national survey was conducted in 2010-2011. Mass drug administration (MDA) for schistosomiasis and STH began in 2012 following the completion of the survey. The Ministry of Health and Child Care and the Ministry of Primary and Secondary Education have partnered to deliver medicines through

STH prevalence
(age-standardised %)



Source: Global Burden of Disease Study 2017

Schistosomiasis prevalence
(age-standardised %)



Source: Global Burden of Disease Study 2017

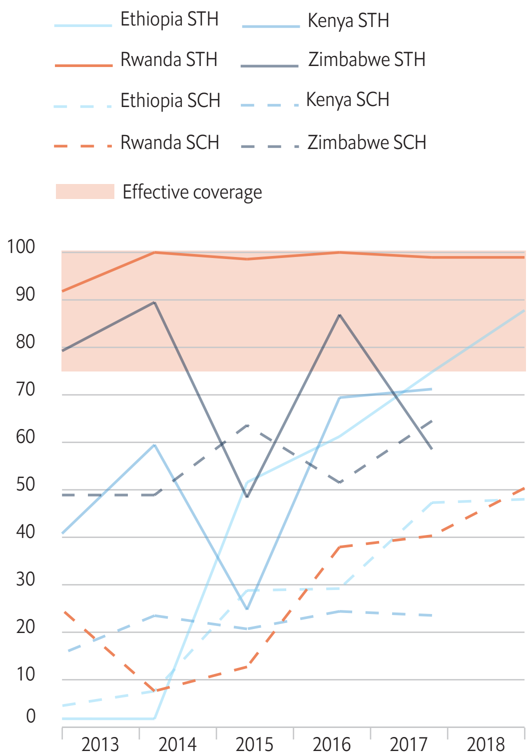
schools across the country since 2012. The government has successfully been able to allocate funding for NTDs through providing salaries for essential community health workers who are able to carry out control and elimination strategies. These workers make it possible to complete activities such as MDA and surveillance.

The increasing focus on NTDs was reflected in the National Health Strategy 2016-20, which included reduction in morbidity due to schistosomiasis and STH and other NTDs by 50% by 2020 as one of its objectives. There are signs that this goal could be achieved.

Zimbabwe's rates of STH have fallen by almost a third since 2000, with 12.7% (1.8m) of the population affected in 2017.[84] Its rate is the second lowest among our four countries. Zimbabwe's progress against schistosomiasis has been greater. It has the highest coverage of preventive chemotherapy against schistosomiasis among our countries (64.5% nationally) and prevalence rates have fallen by almost two-thirds since 2000. About 5.2% (0.6m) of the population were affected in 2017, the lowest rate of any of our countries. The reduction in rates is likely to also be in part down to the prolonged drought, which has reduced survival among the water snails which are needed for the schistosome life cycle.[85]

Zimbabwe's progress towards elimination could be at risk. While coverage of preventive chemotherapy treatment (PCT) had been increasing (nearly 5m treatments for NTDs were distributed in 2017), the latest WHO estimates indicate that Zimbabwe did not administer any PCT for schistosomiasis or STH in 2018.[86,87] With nearly 6m children in need of PCT for STH and nearly 4m individuals in the country in need of PCT for schistosomiasis, rates are likely to increase unless deworming treatment continues.

PCT coverage (%) in our focus countries 2015-2018*



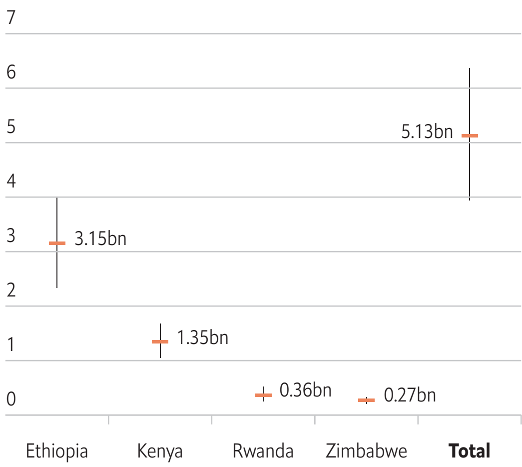
*SCH=PCT coverage for schistosomiasis; STH=PCT coverage for STH.
For STH the graph shows national coverage of school-age children with albendazole.

Economic impact of eliminating STH and schistosomiasis

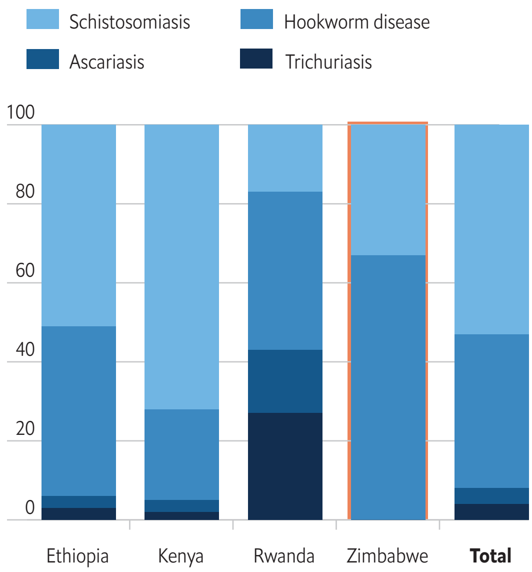
Overall, Zimbabwe stands to gain US$0.3bn in purchasing power parity (PPP) terms (US$0.2bn at market exchange rates) between 2021 and 2040 if the WHO's elimination targets for 2030 are hit.[88] To put this into context this equates to 8% of the country's total spend on health in 2017.

Impact of achieving 2030 WHO targets: GDP gains 2021-40 (US$ billion at PPP)

Horizontal red bars indicate central value, and vertical grey bars indicate upper and lower limits based on uncertainty intervals for prevalence figures from the 2017 Global Burden of Disease study.



Impact of achieving WHO 2030 targets: Proportion of productivity gains (%) attributable to each disease, 2021-40



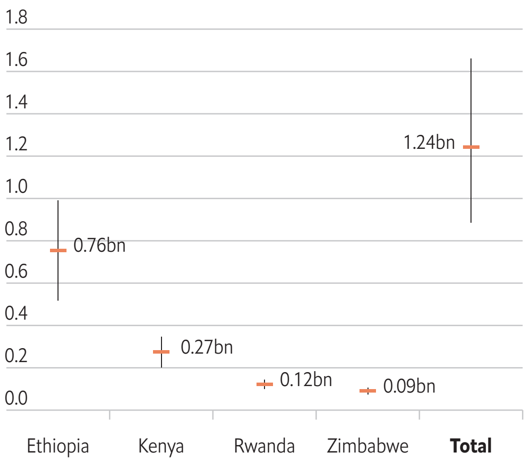
Total losses are smaller for Zimbabwe than the other countries owing to its lower rates of schistosomiasis, smaller population and the fact that its economy is the second smallest after Rwanda. The potential gains are mostly due to the elimination of hookworm disease (67.2%), with almost all of the remainder due to schistosomiasis (32.7%) and a negligible amount due to ascariasis (0.03%). The limited impact of ascariasis and trichuriasis are due to Zimbabwe being estimated in Global Burden of Disease 2017 data as having no or very few cases of the heavy infestations of these worms that are associated with productivity loss in our model. In general published data regarding worm infections Zimbabwe are limited, meaning that some of the inputs into disease modelling in Global Burden of Disease study have been extrapolated from other countries in the region. As more detailed data from Zimbabwe become available these estimates may be revised.

The Zimbabwean economy is in a significantly worse position than those of the other countries we have covered. According to Economist Intelligence Unit data GDP in Zimbabwe is estimated to have contracted by 8.1% in real terms in 2019. Covid-19 is expected to exacerbate this, with a contraction of 15.5% predicted in 2020. A return to growth is predicted in 2022.[89] Given the volatility of the Zimbabwean economy, the use of flat rates of future GDP in our analyses seems suitably cautious.

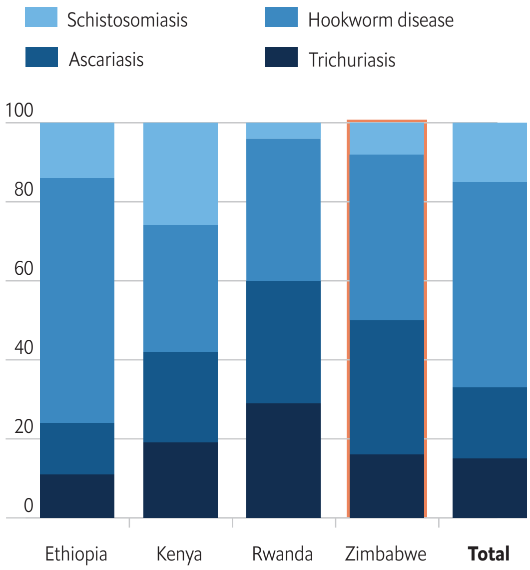
Hitting the WHO 2030 targets would reduce the number of school children affected by these diseases, and the improvement in their health could allow greater educational attainment and wage earning potential. Using estimates from the literature of the possible extent of this educational gain and the link between years of schooling and wages, we modelled this potential gain.

Impact of achieving 2030 WHO targets: Gains in income 2021-40 through better education (US$ billion at PPP)

Horizontal red bars indicate central value, and vertical grey bars indicate upper and lower limits based on uncertainty intervals for prevalence figures from the 2017 Global Burden of Disease study.



Impact of achieving WHO 2030 targets: Proportion of income gains (%) attributable to each disease, 2021-2040



Our analyses suggest that the reduction in these worm infections among school children in Zimbabwe between 2021 and 2040 could boost their salaries by a total of almost US$0.1bn at PPP (US$0.04bn at market exchange rates) once they enter the workforce.

The vast majority of this impact (92%) would be due to the reduction in STH, with 41% due to reduction in hookworm disease, 34% to ascariasis and 16% to trichuriasis. The elimination of schistosomiasis only accounts for 8% of potential the gains, reflecting its lower prevalence among school-age children.

As there is controversy over the extent of any educational benefits arising from deworming, our figures take a conservative approach to potential benefits. For example, we use a conservative estimate of potential benefit from deworming (a maximum of 0.15 grade of schooling gained). Our analyses also use the salaries of the lowest income quintile, to reflect the population affected by these worms, and use a flat rates of future salaries.

Zimbabwe has shown impressive progress in reducing its rates of both schistosomiasis and STH Achieving this target for schistosomiasis could be within reach, but it will require more effort for STH. However, the country's economic woes could jeopardise progress, as could a lack of good data—particularly as elimination is approached and more locally targeted efforts are needed. Sanitation standards have also decreased, creating another hurdle.

The way forward: Multi-stakeholder support for a unified strategy

There is a government NTD strategy for Zimbabwe, but it is not publically available. The current National Health Strategy (covering 2016-2020) lists the reduction of morbidity due to NTDs as a goal. The WHO recommends that Zimbabwe develop guidelines for major NTDs in line with the WHO's Zimbabwe country co-operation strategy for 2016-2020.[90] The National Health Strategy does not mention broader hygiene and behaviour-change measures or vector control as a strategy for reducing morbidity due to NTDs.[91] Without these complementary interventions, true elimination (interruption of transmission) through MDA alone will be nearly impossible.

Zimbabwe's most recent national study on schistosomiasis and STH only surveyed youths aged 10-15 years old. To develop robust elimination strategies it is vital for Zimbabwe to gain a better understanding of the distribution of these diseases in adults and preschool-age children.[92] It will also be important to gain a clear understanding of what is happening at the sub-district level. This process (often referred to as micro-mapping or community-wide mapping) would allow policymakers to adapt elimination strategies within a district, which is especially important if districts are large and have varying prevalence rates. The lack of baseline data for these diseases in non-school-age populations makes it harder to draw meaningful conclusions about the success of elimination strategies.

There is also an urgent need to improve education on NTDs within the primary school curriculum on hygiene and sanitation practices. This type of education is a crucial part of behaviour-change communication. Beyond education within schools, community-wide education is increasingly important. Although awareness of schistosomiasis is high, knowledge on the mode of transmission and preventive measures remains low.[93] Education alone will not be nearly as impactful if access to basic sanitation is not improved, as individuals cannot apply their new knowledge into practice without structural changes to their communities.

Zimbabwe has the potential, through co-ordinated action, to accelerate its progress on NTDs. Success in eliminating STH as a public health problem should serve as a catalyst and example for what can be done when transparent and prioritised strategies take place nationwide.

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