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Costs of Health Care Associated Infections from Inadequate Water and Sanitation in Health Care Facilities in Eastern and Southern Africa

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Abstract

In Sub-Saharan Africa, health care facilities face critical challenges in water supply, sanitation, and hygiene services; health care waste management; and environmental cleanliness. With coverage below 50 percent, these deficiencies pose significant health risks to patients and health care workers, contributing to health care–associated infections. Meta-analyses and individual studies estimate rates of health care–associated infections in Sub-Saharan Africa at between 13 and 30 percent of hospital admissions, impacting patients, families, and health care providers. Rising antimicrobial resistance further exacerbates health outcomes and costs. In Eastern and Southern Africa, an estimated 3.1 million health care–associated infections in 2022 incurred over 320,000 excess deaths, costing at least US$6 billion, or 1.14 percent of combined gross domestic product in 2022. Investing in comprehensive water supply, sanitation, and hygiene and health care waste management can yield substantial benefits, with a benefit-cost ratio of 5.8 for all economic costs. Beyond preventing health care–associated infections, improved cleanliness and infrastructure are crucial for patient satisfaction, impacting future health care–seeking behavior and health care worker job satisfaction. Sub-Saharan African countries should prioritize infrastructure investment, budget allocation, staffing, and behavioral improvements to enhance the quality of health care and mitigate these pressing challenges.

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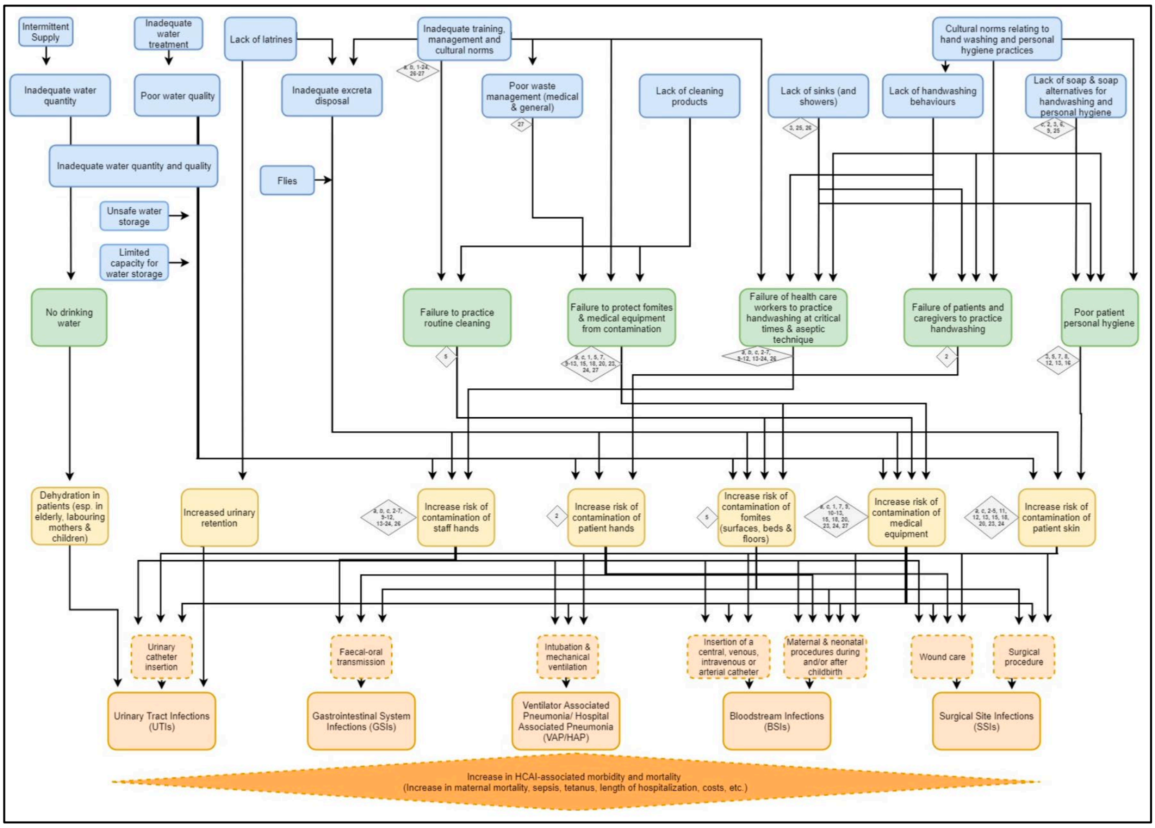
1. Introduction

Importance and causes of healthcare associated infection

Healthcare associated infections (HAI) remain a global health challenge. An HAI is a condition resulting from an infection acquired while a patient is present in a health care setting (Horan et al, 2008).[1] HAIs impact patients and their families by causing illness, prolonged hospital stay, potential disability, excess costs and sometimes death. HAIs help drive the challenges associated with antimicrobial resistance (AMR) and as a result are more costly to treat and impact the patient's health more (Serra-Burriel et al, 2020). Rates of HAI are elevated in Sub-Saharan Africa due to poor infection control practices, inappropriate use of limited resources, under-staffing of healthcare facilities and overcrowding of hospitals (Irek et al, 2018; Ogunsola et al; 2020). Pooled estimates from Abubakar et al (2022) estimate 12.76% (95% confidence interval 10.30 – 15.23) of inpatients are infected with an HAI. However, single-hospital studies from SSA show significantly higher rates, especially for surgical site infections.

HAIs have multiple causes. Khan et al (2017) identify three major reservoirs and transmission routes: (1) endogenous native microflora of patient leading to cross-infection from one site to another; (2) direct patient-to-patient or staff-to-patient pathogen transmission (hands, saliva, fecal matter); and (3) other environmental sources (water, food, equipment, surfaces, and waste). Watson et al (2019) map the transmission pathways for different types of HAIs stemming from inadequate water, sanitation, hygiene, and HCWM services, shown in Figure 1. Health care waste, especially contaminated surgical waste, often acts as a reservoir for pathogenic virulent microorganisms, and it is suggested that 20%–25% of the waste produced by health care outlets is of a toxic nature and considered to have high potential to cause HAIs (Khan et al, 2017). HAIs can also be due to implants and prostheses, most commonly including central line-associated bloodstream infections (CLABSIs), catheter-associated UTIs, and ventilator-associated pneumonia (VAP) (United States CDC, 2023).

Figure 1. Conceptual framework visualizing the relationship between water, sanitation, and hygiene (WASH) and HAIs.



Source: Watson et al (2019)

The role of WASH, health care waste management and environmental cleaning in preventing healthcare associated infection

The availability of clean WASH facilities, overall health facility cleanliness, and the appropriate management of health care waste are particularly important to reduce the risks of spreading diseases and represent preventable pathways based on current best practices (Watson et al, 2019; Monegro et al, 2023; Ducel et al, 2002; Pittet et al, 2006).

The service levels for WASH in healthcare facilities are shown in Figure 2. In SSA, coverage of these essential services in healthcare facilities remains at or below 50% for public healthcare facilities: basic water supply 52%, basic sanitation 13%, basic hygiene 38%, basic HCWM 39%, and basic environmental cleaning 26% in rural areas (WHO and UNICEF, 2022). However, there is a lack of routine data on these essential aspects of healthcare in many countries, suggesting that these basic conditions for patient and health worker safety are largely absent in SSA.

Figure 2. Service ladders for WASH in health care facilities

For more information on the WHO/UNICEF JMP service ladders for monitoring WASH in health care facilities refer to the core questions and indicators[1].

	Higher levels of service	Basic service	Limited service	No service
WATER	To be defined at national level	**Water is available from an improved source[2] on the premises**	An improved water source is within 500 metres of the premises, but not all requirements for basic service are met	Water is taken from unprotected dug wells or springs, or surface water sources; or an improved source that is more than 500 metres from the premises; or there is no water source
SANITATION	To be defined at national level	**Improved sanitation facilities[3] are usable, with at least one toilet dedicated for staff, at least one sex-separated toilet with menstrual hygiene facilities, and at least one toilet accessible for people with limited mobility**	At least one improved sanitation facility is available, but not all requirements for basic service are met	Toilet facilities are unimproved (e.g. pit latrines without a slab or platform, hanging latrines, bucket latrines) or there are no toilets
HAND HYGIENE	To be defined at national level	**Functional hand hygiene facilities (with water and soap and/or alcohol-based hand-rub) are available at points of care, and within 5 metres of toilets**	Functional hand hygiene facilities are available either at points of care or toilets but not both	No functional hand hygiene facilities are available either at points of care or toilets
HEALTH CARE WASTE	To be defined at national level	**Waste is safely segregated into at least three bins, and sharps and infectious waste are treated and disposed of safely**	There is limited separation and/or treatment and disposal of sharps and infectious waste, but not all requirements for basic service are met	There are no separate bins for sharps or infectious waste, and sharps and/or infectious waste are not treated or disposed of safely
ENVIRONMENTAL CLEANING	To be defined at national level	**Basic protocols for cleaning are available, and staff with cleaning responsibilities have all received training**	There are cleaning protocols, and/or at least some staff have received training on cleaning	No cleaning protocols are available, and no staff have received training on cleaning

[1] Core questions and indicators for monitoring WASH in health care facilities in the Sustainable Development Goals. Geneva: World Health Organization; 2018 (https://apps.who.int/iris/handle/10665/275783, accessed 17 May 2023).

[2] Improved water sources are those whose design and construction enable them to deliver safe water. They include piped water, boreholes or tubewells, protected dug wells, protected springs, rainwater, and packaged or delivered water.

[3] Improved sanitation facilities are those designed to hygienically separate human excreta from human contact. They include wet sanitation technologies (e.g. flush and pour flush toilets connecting to sewers, septic tanks or pit latrines) and dry sanitation technologies (e.g. dry pit latrines with slabs, composting toilets).

Source: Water, sanitation, hygiene, waste and electricity services in health care facilities: progress on the fundamentals. 2023 global report. Geneva: World Health Organization and the United Nations Children's Fund (UNICEF), 2023.

Disease burden associated with healthcare associated infections

HAIs lead to massive preventable health burden. It is estimated that approximately 20% of all-cause global deaths are due to sepsis: around 11 million potentially avoidable deaths per year (WHO, 2020; Rudd et al, 2020). In SSA, sepsis accounts for 3% of maternal complications and 10% of maternal deaths (Bailey et al, 2017). There are an estimated 2.6 million cases of neonatal sepsis per year leading to 250,000 deaths (Seale et al 2014). In East Africa the neonatal sepsis rate is estimated at 30% of live births (Abate et al, 2020). According to Zaidi et al (2005), more than half of all infants in neonatal units in developing countries acquire an HAI, with a fatality rate ranging between 4%–56%.

Antimicrobial resistance is a major cause for concern, given the waning efficacy of frontline drugs to treat bacterial and viral infections. AMR is the ability of a microorganism (such as bacteria, viruses, fungus, and some parasites) to stop an antimicrobial (such as antibiotics, antivirals, antifungals and antimalarials) from working against it. As a result, standard treatments become ineffective, infections persist and worsen, and may spread to other patients and to healthcare workers. Poor infection control and inadequate sanitary conditions contribute to the spread of AMR.

WASH, HCWM and environmental cleaning services play a key role in stemming the tide of HAIs. Monegro et al (2023) state that universal standard (infection control) measures, such as handwashing with soap and water or using alcohol-based disinfectant before and after each patient visit, are vital in reducing rates of transmission of multi-drug resistant pathogens. Similarly, the WHO practical guide on hospital acquired infections advises three main prevention strategies: patient risk classification, patient-to-patient hygiene measures, and environmental hygiene measures (Ducel et al, 2002). WHO's World Alliance for Patient Safety advocates that effective hand hygiene is the single most important practice to prevent and control HAIs, which form colonies with multi-drug resistant microbes (Pittet et al, 2006).

The economics of healthcare associated infections

In implementing measures to control HAIs in general, and AMR in particular, economic considerations are vital to consider in making the best use of limited healthcare resources. Several types of economic study provide different perspectives on the control of HAIs, including cost-of-illness, cost of prevention, cost-benefit analysis, cost-utility analysis, and cost consequence analysis. A rich literature exists on the health and economic consequences of HAIs, although this is mainly in OECD countries (Serra-Burriel et al, 2020).

Cost-of-illness studies estimate the medical costs and economic losses due to HAIs. For SSA, Epeh and Fenny (2022) report results for 13 studies estimating additional medical costs and average length of stay (ALOS) due to HAIs, finding significant heterogeneity across studies. In Ethiopia, Gidey et al (2023) compare the cost of treating HAI versus non-HAI patients and find an additional cost of US$58 per HAI (US$6.0 for procedures and investigations, US$4.7 for hospital bed and US$47.2 for drugs) and additional ALOS of 8.3 days. In Ghana, Otieku et al (2023) find that having an HAI increases drug cost by 9% and increased laboratory cost by 85%, and ALOS by 3 days. In Ethiopia, pediatric admissions with HAI have 5 days longer ALOS than without HAI (Sahiledengle et al, 2020). In Tanzania, postoperative hospital stay is 7.6 days longer for patients with HAI (Eriksen et al, 2003). In Rwanda, HAI increase ALOS by 3.6 days (Sutherland et al, 2019).

Antimicrobial resistance increases the costs of medical care, through the need for more procedures, drugs and longer stay. In Ghana, Otieku et al (2023) found that an AMR infection increased drug cost by 30%, increased laboratory cost by 42%, and ALOS by 4.9 days. From 20 studies (19 OECD countries and 1 China), multi-drug resistant HAIs cost an additional 33%, with 27% increase in ALOS (Serra-Burriel et al, 2020).

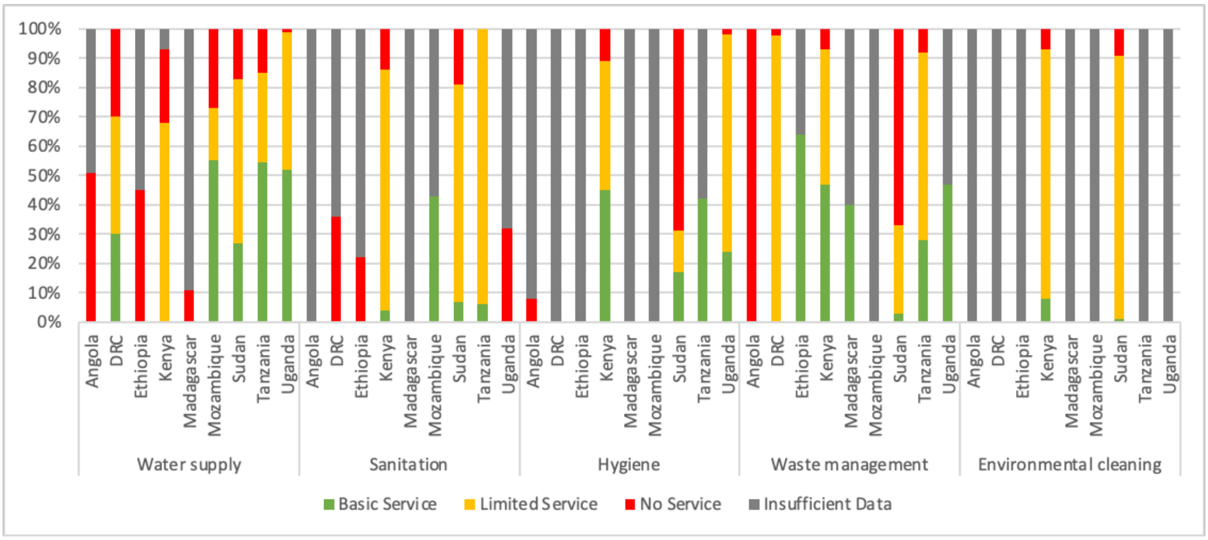
At the macroeconomic level, the World Bank concludes that the economic costs of AMR may be within the same order of magnitude as those of the major 2008 global financial crisis, or a loss of global GDP of 0.14% every year, with more pronounced negative impacts in low-income countries (World Bank, 2017). Their estimates include AMR in both animals and humans. Dadgostar (2019) reports that about 10 million people will die across the world annually by 2050 if strong and effective action against AMR is not taken and could cost health systems from US$300 billion to more than US$1 trillion annually by 2050 worldwide. OECD (2018) estimates that between 2015 and 2050, up to US$3.5 billion (at Purchasing Power Parity) is expected to be spent yearly on AMR-related complications across 33 OECD and EU countries. This corresponds to 10% of health care costs caused by communicable diseases.

The costs of interventions to improve basic WASH and HCWM services in healthcare facilities was estimated for 46 low-income countries (Chaitkin et al, 2022), finding that the cost per capita needed is US$0.30 for capital cost and starting at US$0.10 for recurrent cost going up to US$0.51 per year at full coverage (Chaitkin et al, 2022). A review on the costs of WASH in healthcare facilities in low- and middle-income countries found 36 studies, with piecemeal information for different service types and levels but limited evidence for giving a picture of the resource needs on the continent (Anderson et al, 2021).

Study focus on Eastern and Southern Africa

In SSA, there is a lack of routine monitoring on WASH, HCWM and environmental cleaning in healthcare facilities, although it has been improving since the WHO/UNICEF Joint Monitoring Programme (JMP) started compiling statistics in the SDG era. Figure 3 shows the latest data available in the nine countries from Eastern and Southern Africa included in this study. Data on environmental cleaning are available for only 2 of the 9 countries, and there are major data gaps for basic sanitation and basic hygiene. Lack of data would suggest that these basic conditions for patient and health worker safety are largely absent. To provide a better picture of coverage in healthcare facilities, these data compiled by the JMP can be supplemented with other data available from the study countries, although attention is needed on quality and national representation of additional data. For example, in Tanzania between 2005 and 2010, it was found that only 24% of health facility delivery rooms were “WATSAN-safe” (Benova et al, 2014).

Figure 3. Coverage of WASH, HCWM and environmental cleaning in healthcare facilities in 9 Eastern and Southern African in 2021



Source: Global progress report on water, sanitation and hygiene in health care facilities: fundamentals first. Geneva: World Health Organization; 2020. License: CC BY-NC-SA 3.0 IGO.

The SSA region is disproportionately affected by AMR, with rates well over 50% for many frontline drugs (Murray et al, 2019), in part owing to the high burden of infectious diseases, poor regulation of antimicrobial use, and a lack of alternatives to ineffective antimicrobials (Kariuki et al, 2022). For neonatal sepsis, 31% of mortalities (690,000) reported were plausibly attributed to antimicrobial-resistant infections (Li et al, 2020).

In conclusion, while evidence is quite favorable for the return on investing in WASH, HCWM and environmental cleaning, the evidence for SSA is weak. This study aims to fill several gaps in our understanding of the damage costs of inadequate WASH, HCWM and environmental cleaning in healthcare facilities. The study takes a more comprehensive perspective on the health economic impacts of poor WASH, HCWM and environmental cleaning in healthcare facilities than other studies in the literature, including the value of patient productivity and avoided mortality in the estimates. Second, the study fills a gap in the literature and provides a multi-country assessment of the cost of HAIs in several African countries.

2. Methods

Overall study scope

Using a standard cost-of-illness methodology, a quantitative model was constructed to combine several variables to estimate the economic costs to society of HAIs. Nine countries of Eastern and Southern Africa were selected based on their contribution to lack of WASH, HCWM and environmental cleaning in healthcare facilities in this region: Angola, DRC, Ethiopia, Kenya, Madagascar, Mozambique, Sudan, Tanzania, and Uganda.

Three categories of cost were summed up to estimate the cost-of-illness (or damage costs) of HAIs: medical costs, productivity costs and mortality costs. To provide relevant information for healthcare decision makers, the proportion of HAIs that could be prevented through comprehensive WASH, HCWM and environmental cleaning measures were assessed and compared with the approximate costs of these control measures, to generate a benefit-cost ratio.

All estimates are made in United States dollars using average exchanges rates in 2022 and costs are presented in 2022 prices. Given the uncertainty of the parameters within the model, sensitivity analysis is conducted on selected parameters.

Other impacts of poor WASH, HCWM and environmental cleaning in healthcare facilities are less well quantified in the literature. Several impacts relating to quality of care and patient satisfaction are described by drawing on global and African literature. The combined quantitative and qualitative analysis therefore provides an overall picture of the consequences of inadequate WASH, HCWM, and environmental cleaning services in healthcare facilities.

Economic consequences of healthcare-associated infections

Several consequences of HAIs have an associated cost, as reviewed by Morel et al (2020), Shrestha et al (2018) and McGowan (2001). While these cited studies focus on AMR HAIs, they are relevant for HAIs more broadly. Morel et al (2020) develop a comprehensive list of direct and indirect costs. Shrestha et al (2018) further categorize the costs from the perspective of patients, the health system, and society at large. Due to data and time limitations, the present study does not estimate all the costs identified as being relevant. The costs included are micro-economic costs based on the estimated number of HAIs, calculated as the proportion of inpatients being infected with an HAI multiplied by the total inpatient admissions in each country in one year, and the associated patient and healthcare costs (see Table 1). Further details on data sources and values used are provided in Annex 1.

Healthcare costs are estimated based on the number of HAIs annually multiplied by the additional cost of treating a patient with an HAI (drug and laboratory costs and longer average length of stay (ALOS)), separately for AMR and non-AMR HAIs. Costs are estimated differently for patients admitted at health clinic (primary), district hospital (secondary) and higher hospital (tertiary) levels, using unit costs per inpatient bed and drug and laboratory costs at each level (see Table 1).

Productivity losses are estimated based on the number of annual HAIs multiplied by the average number of days of additional time loss due to HAI multiplied by the daily value of time. The time losses of both patient and caregiver time are included. The daily value of time is conservatively estimated using the value-added per agricultural worker.

Table 1. Variables, data needs and sources for economic assessment of HAIs

Cost variable	Data needs	Data value or range across countries (range for sensitivity analysis)	Data source
Healthcare cost-of-illness			
Annual healthcare associated infections (HAIs)	Average % of admissions infected with HAI	12.76% (6.4% - 25.6%) used in 8 countries	Abubakar et al (2022)
		17.0% (8.5% - 34.0%) used in Ethiopia	Alemu et al (2020)
	Proportion of HAIs that are AMR	50% (25% to 70%)[2]	Kariuki et al (2022), Murray et al (2022)
	No. of annual hospital admissions	2.5 – 11.2 admissions per 100 population[3]	Ministry of Health
Additional cost of treating a patient with an HAI[4]	Average hospital cost per day ('hotel' cost)	I: US$5.98-US$55.6 II: US$9.6-US$54.06 III: US$17.63-US$206.4[5]	IHME (2014, 2015)
	Cost of drugs and laboratory tests per HAI (no AMR)	I: US$11.8 to US$49.0[6] II: US$28.2-US$117.6[7] III: US$129.5-US$539.5[8]	Gidey et al (2023) Aerts et al (2022) Bocoum et al (2019)
	Cost of drugs and laboratory tests per HAI with AMR	Double the costs of HAI (above) for each level of care	Assumption
	Additional length of stay HAI (no AMR)	5 days (3 to 10 days)[9]	Fenny et al (2020)
	Additional length of stay HAI with AMR	10 days (6 to 20 days)[10]	Otieku et al (2023)
Productivity cost-of-illness			
Annual HAIs	Same as Healthcare cost		
Additional days for recovery after HAI	Additional recovery time after having HAI	2 days	Assumption
Loss in value-added of workers	Productivity loss (agricultural value-added)	US$2.1 to US$22.0 per day (US$9 to US$284 per day in industry)[11]	World Bank statistics
	Proportion of HAI patients that are adults	60%	Assumption
	Labor force participation rate	28.3% to 83.6% (female) 50.8% to 89.2% (male)[12]	ILOSTAT (2023)
	Proportion of HAIs suffered by women	60%	Assumption
Loss of time spent in non-productive activities	Average daily value (opportunity cost)	30% of the agricultural value-added	Assumption
Mortality cost-of-illness			
Annual HAIs	Same as Healthcare cost		
Case fatality rate	Case fatality rate HAI (no AMR)	6.9% (4% to 15%)[12]	Gidey et al (2023) and 6 other studies – see Table 9
	Case fatality rate HAI AMR	13.8% (8% to 30%)	Serra-Burriel et al (2020)
Value of a premature death	Value of a statistical life	US$4,113 to US$38,719 (US$18,706 to US$112,449)[13]	Calculation based on Banzhaf (2022)

Mortality cost is estimated based on the number of HAIs annually multiplied by the case fatality rate of HAIs multiplied by the value of a human life. The value of a human life is based on the value of statistical life from the latest meta-analysis from the USA (US$8 million) converted to SSA using the difference in GDP per capita and an income elasticity of 1.5.

The outputs generated include the annual cost of HAIs, including associated AMR, consisting of the direct healthcare costs, productivity losses, and premature mortality. The annual health care cost is presented as a percent of total health spending, and the annual total cost of HAIs is presented as a percent of GDP. Healthcare and total costs are also estimated per population (in entire country) and per admission.

A one-way sensitivity analysis was conducted by varying input values for each variable shown in Table 2. Where indicated, a lower value was not used because the baseline value is already considered conservative. Justification and references for these values are provided in Annex 1.

Table 2. Baseline and low/high values for selected variables in sensitivity analysis

Variable	Low (conservative)	Baseline	High
HAI rate	Half (6.4%)	12.8%	Double (25.6%)
AMR rate	Half (25%)	50%	50% higher (75%)
Cost per hospital bed day	Primary hospital	Secondary hospital	Tertiary hospital
Costs of drugs, supplies, laboratory	-	Mozambique study (district hospital)	Ethiopia study (tertiary hospital)
HAI excess length of stay (impacts AMR and productivity cost)	3 days	5 days	10 days
Value of productive time	-	Value added per worker/year in agriculture	Value added per worker/year in industry
Case fatality rate	4.0%	6.9%	15.0%
Value of life	-	Extrapolated from USA based on difference in GDP using income elasticity of 1.5	Extrapolated from USA based on difference in GDP using income elasticity of 1.2

Several costs associated with HAIs as identified by Morel et al (2020) are excluded, either because they are unlikely to be saved in the short- to medium-term (e.g. surveillance and containment programs, education programs and public health or information campaigns) or because they are difficult to quantify and few or no estimates exist in the literature (e.g., cost of unoccupied beds due to isolation, funeral costs and psychological impacts). Treatment of HAIs in healthcare workers are excluded due to lack of estimates. Overall, estimated costs are conservative, drawing on average unit costs that would be typical at secondary hospital level and not considering the additional costs of complications, long-term ICU stay, long-term care and rehabilitation, disability benefits, and expensive pharmaceuticals which might be required in some cases. For AMR, the costs of second-line drugs are used.

Averted HAI cases and deaths from delivering basic WASH services

High quality intervention studies that isolate the impact of WASH interventions on HAIs are rare, especially in an African context. Studies from SSA and from the rest of the world show variation in effectiveness of WASH interventions, from significant impact (above 50%), to marginal impact (below 40%), to no impact. The impact that improved WASH has on HAI numbers depends on the baseline HAI rates, main transmission pathways and patient risks, and the intensity of and compliance with the intervention. Table 3 presents a summary of selected key literature, in particular systematic reviews, supplemented with intervention studies from SSA. More than half of all cases of health care-associated sepsis are thought to be preventable through safe WASH services and appropriate IPC measures (WHO, 2020; Rudd et al, 2020). Shreiber et al (2018) suggest a sustained potential for the significant reduction of HAI rates in the range of 35%–55% associated with multifaceted interventions, irrespective of a country's income level. Infection control measures during norovirus outbreaks are estimated to be associated with 0.6 (95% CI: 0.3–1.1) times smaller patient case counts (Adams et al, 2022).

Table 3. Select studies presenting the impact of WASH interventions on HAIs

Author (year)	Type of publication	Studies included	HAI reduction achieved
Watson et al (2019)	Systematic review	3 cohort studies	39% to 50%
		27 before-and-after studies	Statistically significant reduction in at least one HAI in 26 studies (full details in article supplementary materials)
Schreiber et al (2018)	Systematic review	144 studies	The pooled incidence rate ratios associated with multifaceted interventions were 0.543 for CAUTI, 0.459 for CLABSI, and 0.553 for VAP. The pooled rate ratio was 0.461 for interventions aiming at SSI reduction, and 0.509 for VAP reduction initiatives.
Umscheid et al (2011)	Systematic review	64 studies	65%–70% of cases of CABSI and CAUTI and 55% of cases of VAP and SSI
Luangasanatip et al (2015)	Systematic review	19 studies	The efficacy of the WHO 2005 campaign (WHO-5) reported clinical outcomes in 19 studies. Impacts were consistent with clinically important reductions in rates of infection resulting from improved hand hygiene for some important hospital pathogens.
Adams et al (2022)	Systematic review	102 papers describing 162 norovirus outbreaks	Control measures were implemented in 118 (73%) outbreaks and were associated with 0.6 (95% CI: 0.3–1.1) times smaller patient case counts and 0.7 (95% CI: 0.4, 1.0) times shorter durations in hospitals.
Dramowski et al (2022)	Intervention study	1 intervention study from South SSA	Neonatal bloodstream infection rate declined following implementation of the NeoCLEAN intervention, from 6.7 to 3.9/1,000 patient days ($p = 0.166$).
Aiken et al (2012)	Intervention studies on SSI prevention in SSA	24 studies from 9 SSA countries	Several studies indicated that alcohol-based hand rubs could provide a low-cost alternative to traditional surgical hand-washing methods.
Fenny et al (2022)	Intervention study of alcohol hand rub	1 study from Ghana	Neonatal bloodstream infection-attributable deaths decreased by 73% and extra length of hospital stay (LOS) decreased by 50%. The post-intervention assessment revealed the ABH program contributed to 16% decline in the incidence of neonatal bloodstream infections at the NICU.

Based on these findings, the present study uses a baseline reduction in HAIs (and associated case fatality) of 50%, with a range of between 25% to 75% reduction. As presented in Watson et al (2019), before-and-after studies have reported higher percentage reductions in HAIs from the baseline, following prolonged implementation of the WASH measures. Hence, a baseline estimate of 50% reduction in HAIs is likely to be conservative.

Cost of WASH and HCWM interventions

The study draws on Chaitkin et al, 2022 for costs to achieve basic WASH and waste management in healthcare facilities in 46 low-income countries. These include costs for water supply, sanitation, hygiene and HCWM, as per WHO/UNICEF Joint Monitoring Programme definitions for SDG monitoring. Costs are estimated from the provider perspective and include upfront investments (capital costs), annual operations and periodic maintenance costs for hospitals and non-hospitals in both urban and rural settings.[14] Eight out of the nine focus countries were included in these 46 countries (Kenya excluded). The average cost data for 46 countries[15] from Chaitkin et al (2022) were updated to 2022 values using the GDP deflator for each country.

Benefit-cost ratio

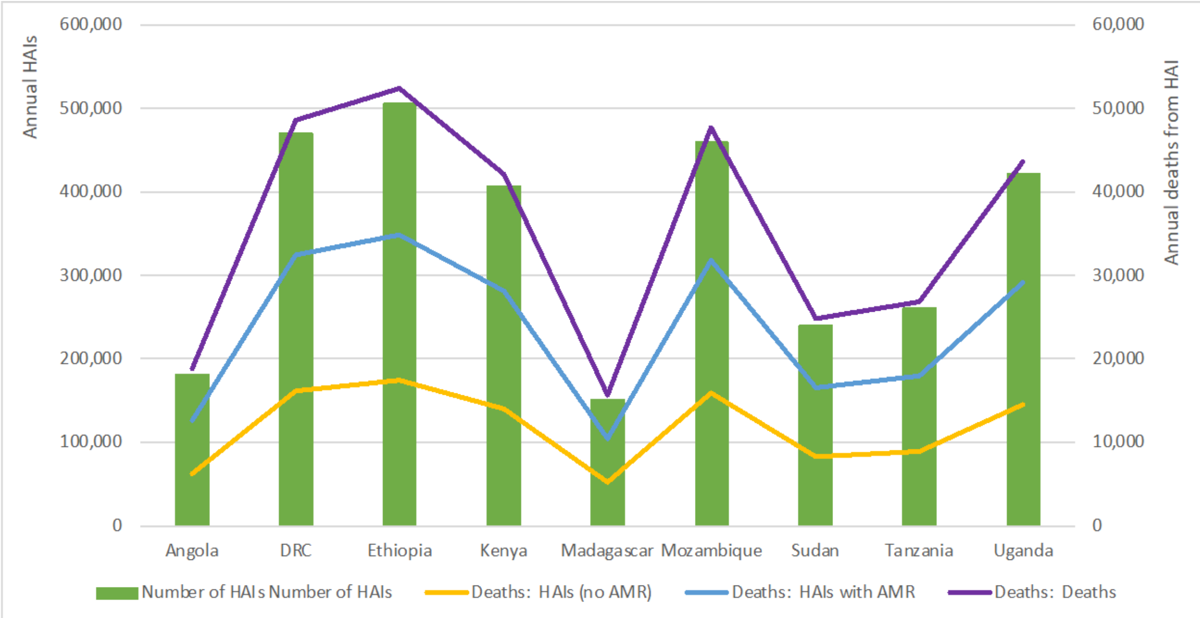
The benefit-cost ratio is calculated as the average economic savings per capita (across the entire population) divided by the average cost per capita of achieving universal coverage of basic WASH in healthcare facilities across nine countries.

3. Results

Disease burden due to healthcare associated infection.

The total number of HAIs is estimated to be 3.1 million in 2022 in 9 countries of Eastern and Southern Africa, as shown in Figure 4. The number of deaths resulting from these HAIs is estimated to be 320,000 in 2022. The number of HAIs and deaths is closely related to the population size, and hence the number of hospital admissions, with the highest numbers in Ethiopia and Mozambique. That said, drawing on official government data, admissions per 100 population vary widely from 2.5 per 100 population in Ethiopia to 11.2 per 100 population in Mozambique, hence explaining some of the differences in HAI costs.

Figure 4. Estimated number of healthcare associated infection and related deaths in 9 countries in Eastern and Southern Africa

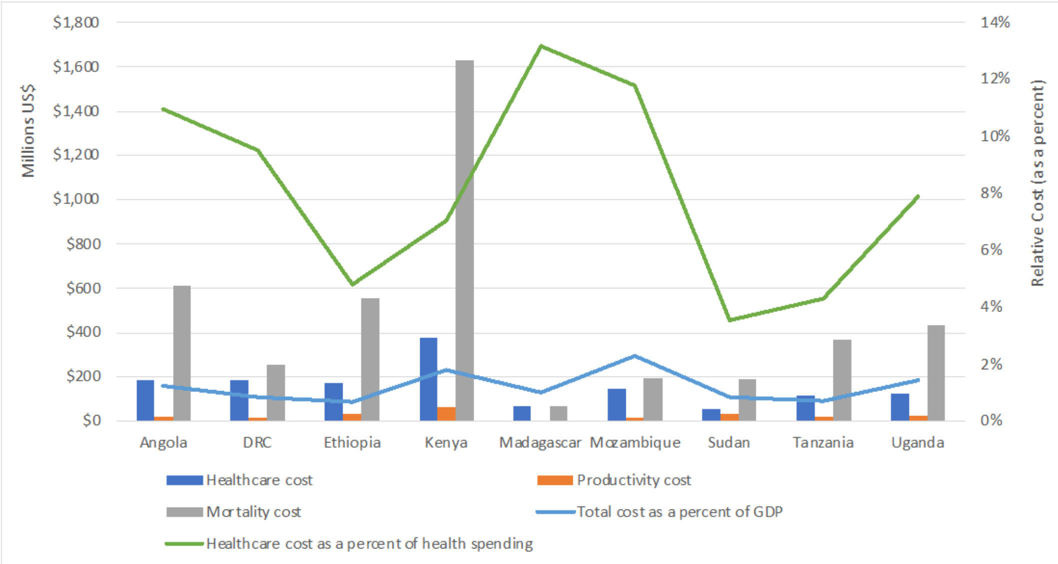


Source: author estimates

Economic impacts due to HAIs

Economic estimates were aggregated from the healthcare costs, the productivity losses and the premature deaths associated with HAIs, including AMR. The total economic losses are at least US$6 billion in 2022 across the 9 countries. As shown in Figure 5, the costs of premature death account for 72% of the total costs, due to the relatively high case fatality rate from HAIs. In Kenya, total costs were US$2.1 billion in 2022, and US$820 million in Angola. Costs as a percent of GDP are highest in Kenya and Mozambique, at 1.8% and 2.3%, respectively. Across the nine countries, total cost as a percent of GDP is 1.14% in 2022, and healthcare cost as a percent of total health expenditure is 7.1%.

Figure 5. Estimated healthcare costs, productivity costs and mortality costs resulting from HAIs in nine countries, and costs as a percent of GDP

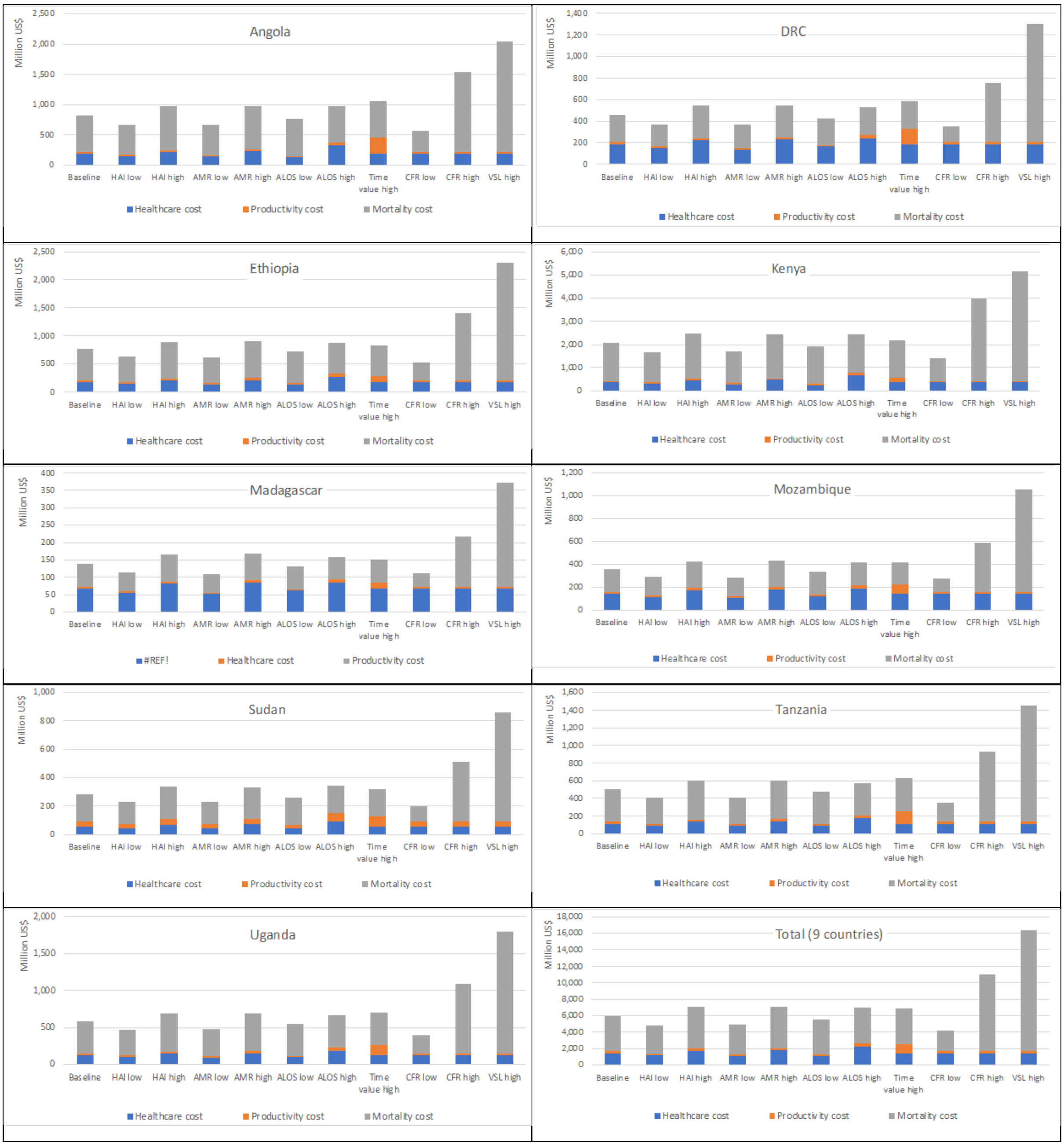


Source: author estimates

Sensitivity analysis

The sensitivity analysis conducted on 6 variables with inherent uncertainty indicates that the cost of illness varies to a moderate degree (Figure 6). The analysis is limited by the fact that input values were varied one at a time, and not in combination. However, combining high (or low) values of several input variables together would generate extreme values which are unlikely to occur in practice. The baseline results are most affected by assumptions for (a) HAI rates, which underly the estimate of all the impacts, on (b) case fatality rates; and on (c) the value of life. The latter two have the greatest impact because premature death accounted for 72% of the impacts under the baseline. The value of time had the greatest impact on the productivity costs. Overall, across the nine countries, the baseline cost of illness of US$6 billion was most affected by (a) value of life assumption, which led to more than a doubling of the total costs to over US$16.4 billion, and (b) lower CFR, HAI and AMR rates which led to reduction in total costs to less than US$5 billion.

Figure 6. Results of sensitivity analysis



Source: Author estimates. Key: HAI – healthcare associated infection; AMR – antimicrobial resistance; ALOS – average length of stay; CFR – case fatality rate; VSL – value-of-statistical-life.

Cost-benefit analysis

Across the nine countries, the annual healthcare costs per capita (across the entire population) was US$2.75, or US$2.04 per capita for the low-income countries.[16] This compares with a total economic cost of US$11.5 per capita for all 9 countries, or US$7 per capita for the low-income countries. The costs of providing basic WASH, HCWM and environmental cleaning in low-income countries is estimated at US$0.81 per capita per year (US$0.30 for capital cost and US$0.51 for recurrent cost when universal coverage is achieved).[17] Assuming 50% reduction in HAIs through the provision of basic WASH, HCWM and environmental cleaning the resulting benefit-cost ratios are 1.22 for financial health care savings alone (1.38 with middle income countries included), and 4.2 for all economic costs (5.8 with middle income countries included)(see Table 4).

Table 4. Estimation of benefit-cost ratios for WASH and HCWM interventions

Countries included	Cost-of-illness per capita		Averted costs (50% reduction)		Intervention costs	Benefit-cost ratio	
	Health care	Total	Health care	Total	Health care	Health care	Total
Low-income	2.04	7.0	1.02	3.5	US$0.83	1.22	4.2
All 9 countries	2.75	11.5	1.38	5.8	US$1.00	1.38	5.8

Source: author estimates. Intervention costs from Chaitkin et al (2022).

4. Discussion

This study has demonstrated that there are major hidden costs of HAIs in SSA. Every day, millions of Africans receive inpatient care in a healthcare facility – whether for a chronic illness or acute disease, surgical procedures or for labor and delivery and postpartum services – but in their vulnerable state an estimated 10% or more of these people become infected by a microorganism while receiving medical care, a high proportion of which are resistant to first, second- and even third-line drugs.

By quantifying the major costs associated with these infections at national level – direct healthcare costs of treatment, productivity losses for the patients, and the value of lost lives – this study shows that the economic costs exceed 1.14% of the GDP of nine countries in Eastern and Southern Africa and the direct healthcare costs exceed 7% of total health spending in these countries.

While efforts were made to select data sources that best reflect the national contexts in the countries of study, there are still some methodological weaknesses, excluded impacts and data limitations associated with a multi-country desk study that is reliant on secondary data sources.

This study adopted a standard cost-of-illness methodology (Morel et al, 2020; Shrestha et al, 2018). While previous studies have assessed the direct healthcare costs of HAIs in SSA (Aerts et al, 2022; Schäferman et al, 2020; Gidey et al; 2023; Otieku et al, 2023), none have included the indirect costs to the patient. Hence, standard economic approaches were used to value the loss of productive time due to a longer time spent away from work or home. In some instances, this loss may be incurred by a caregiver or family member– for example, a woman who has just delivered a baby is unlikely to return to work immediately, but the HAI she contracts may result in a loss of earnings or productive time for a partner or relative.

Quantifying the cost of premature death due to HAI is important, given that a significant proportion of HAIs lead to premature death, especially for AMRs when a more expensive second- or third-line drug is unavailable or unaffordable. This study used value-of-statistical-life (VSL) methodology to quantify the value of life. It did not value disability-adjusted life-years (DALYs) lost due to the lack of data on the age of the patient (and age at death). However, due to the lack of VSL studies in the study countries, VSL was estimated using a meta-analysis of studies from the USA and adjusted for the differences in economic development (GDP per capita) and using a conservative income-elasticity of 1.5. The latter allows for the likelihood that people have a lower willingness to pay for interventions that prevent death when their income is lower. Sensitivity analysis showed that when case fatality increased from 6.9% to 15% and when income elasticity of 1.2 was used instead of 1.5, that the total economic losses increased from US$6 billion to US$11.0 billion and US$16.4 billion, respectively.

Several quantifiable costs of HAIs - and specifically of AMR HAIs - were excluded due to lack of available data and difficulties in aggregating to the national level. These include:

- The costs of surveillance and containment programs, education programs and public health or information campaigns related to HAIs.
- Additional costs of longer-term complications of HAIs, as it was assumed that the initial cost of treatment would lead to either discharge or death. However, some patients may require long-term ICU stay, long-term care and rehabilitation, and disability benefits.

- The cost of HAI patients using beds for several additional days is likely to have an opportunity cost greater than the cost of the bed. Indeed, when patients need to be isolated due to AMR, there may be several unoccupied beds in a ward, thus preventing other patients from receiving the care they need.
- It is possible that HAIs are contracted during outpatient care, which are presumed to be community acquired infections upon hospital admission, underestimating incidence of HAI.
- Adherence to HAI treatment protocols that assume all HAIs are AMR, which could result in lower cost due to more effective treatment or higher cost due to use of more costly second- and third-line drugs in all HAI cases.
- HAI rates and related costs of treating healthcare workers and the costs associated with the loss of capacity while they recover. Furthermore, there is a loss in job satisfaction for healthcare workers working in difficult, dirty conditions, and a risk of absenteeism. In the longer-term, they may decide to change job or even change career.
- Health systems operating at or above their current capacity, with bed occupancy at or above 100%, may be required to turn away prospective inpatients. Hospital admissions would presumably be higher if the health system had higher capacity, which could lead to higher rates of HAIs, or lower in case of less overcrowding.
- Patients (and their social circle) not returning to a healthcare facility due to a previous experience– resulting either in delayed treatment seeking and future worse health outcome, and/or seeking care at a more distant or higher-level health facility, resulting in higher costs.
- The likelihood that future health emergencies or pandemics will be more difficult to prevent and control without adequate investment in WASH, HCWM and environmental cleaning.
- Psychological impacts of being infected with an HAI, especially one that is AMR, and patient dissatisfaction associated with poor quality care and lack of WASH facilities.[18]
- Dissatisfaction of healthcare workers affecting their motivation to work, their treatment of patients, and career choices, which subsequently could affect health outcomes (see Annex 3 for a brief review of quality of care as it pertains to WASH).

This study relied on secondary data sources, including national statistics and published literature. Due to lack of data on costs and HAI rates for some countries, these were extrapolated from countries where data were available, and therefore may not reflect that country's situation. In general, the HAI rates used were reflective of national contexts across SSA, and some countries had sufficient studies presenting HAI rates to make tailored estimates for those countries.

The study assumes that 50% of HAIs are AMR, which likely varies significantly within and across countries, and simplifies the many complexities associated with AMR. However, for the purposes of this analysis an AMR rate of 50% (based on Murray et al (2022)) may be quite conservative, and a more fine-tuned value would need to be used in future national studies based on localized rates and types of infection and resistance levels.

Only a few studies were available from SSA which estimated the direct medical costs of treating HAIs. Hence, estimates drawn from the more representative and better quality studies were extrapolated to other countries. The evidence shows that the costs associated with treating HAIs are highly dependent on the level of the healthcare facility, due to the better availability of diagnostics and more common use of third-line or patented drugs, more often the case in tertiary facilities. This study used cost figures for secondary facilities in baseline analysis. Moreover, while some studies from the region report longer length of stay due to HAI (Karagiannidou et al, 2020), the study used a conservative estimate of 5 days based on Manoukian et al (2018).

A consensus is emerging on the key role that clean WASH facilities, overall health facility cleanliness, and the appropriate management of health care waste play in reducing the risks of spreading diseases within healthcare facilities (Watson et al, 2019; Monegro et al, 2023, Shreiber et al (2018), irrespective of a country's income level. However, there are few studies from SSA that assess the efficacy of comprehensive measures to combat HAIs. Most studies evaluate hand hygiene interventions (Luangasanatip et al, 2015) and IPC (Thandar et al, 2022), while some also evaluate movement restrictions and staff exclusions (Adams et al, 2022) and surveillance. Studies from developed countries suggest that upward of 60% reduction may be achieved. Therefore, it is likely that the 50% HAI reduction chosen from comprehensive WASH and IPC interventions is likely to be a conservative indication of what can be achieved in SSA.

5. Conclusion

WASH, HCWM and environmental cleaning are lacking as central features of quality of care in healthcare systems throughout the world, especially in low-resource settings in SSA. In the countries included in this study well below 50% of health facilities have adequate WASH and HCWM. Indeed, these services are not among the 14 tracer indicators that make up SDG indicator 3.8.1 on quality of care. Yet, between 13% and 30% of hospital admissions in the region result in secondary infection by a microorganism during medical care, impacting patients, families, and healthcare providers. Rising antimicrobial resistance further exacerbates poor health outcomes and costs. In Eastern and Southern Africa, an estimated 3.1 million HAIs in 2022 incurred over 320,000 excess deaths. When all the direct and indirect costs are considered, it is likely that HAIs account for well over 7% of health spending and the economic costs of at least US$6 billion exceed 1% of GDP in the nine study countries. Implementation of WASH, HCWM and environmental cleaning is likely to prevent at least 50% of these costs and have multiple additional benefits on patient and healthcare worker safety and satisfaction. Investing in comprehensive WASH and HCWM can yield substantial benefits, with a benefit-cost ratio of 5.8 for all economic costs. The initial investments as well as ongoing operational costs are likely to be recuperated (wholly or in part) from the savings in monetary costs to the healthcare system and patients. Beyond preventing HAIs, improved cleanliness and infrastructure are crucial for patient satisfaction, impacting future healthcare-seeking behavior and healthcare worker job satisfaction.

Given the additional burden on healthcare systems that are already under considerable strain in the nine study countries, it is critical to define and implement policies for reducing HAIs and AMR. This includes prioritizing infrastructure investment, allocating sufficient budget, staffing, and behavioral enhancements to improve the quality of healthcare and mitigate the associated costs. Additionally, national guidelines on WASH and IPC that are tailored to different levels of care and differently resourced contexts are required. These should be accompanied by cost assessments of the investments needed to provide and sustain WASH and IPC as per the guidelines, with budget allocations that are consistent with the resource needs.

This study has also identified several research gaps. Importantly, decision makers at national level, district level and health facility level need a better understanding of rates of HAIs and AMR, and the impact that these have on health systems, providers, patient outcomes, and the associated additional healthcare costs. Future studies are needed, especially in the SSA region, that provide representative data on hospital admissions, HAI and AMR rates, clinical standard operating procedures for different pathogens, and costs related to treatment and illness. Future work should also assess the benefits of alternative approaches to reducing the incidence of HAIs.

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Annex 1: Detailed data and studies for cost-of-illness estimation

1. Healthcare associated infections

Watson et al (2019) identify five main types of HAI: urinary tract infections, gastrointestinal infections, ventilator associated pneumonia / hospital associated pneumonia, bloodstream infections and surgical site infections. In addition to these, though accounting for fewer HAIs, are respiratory tract infection, skin and soft tissue infection, and ear, eye, nose, and throat infection.

Global reviews and national studies typically provide estimates of HAI numbers as a prevalence at a point in time. Some studies report HAI incidence in terms of patient days with HAI per 1,000 patient days. Only one study in Africa - Abubakar et al (2022) – provides a pooled estimate for HAIs, estimating 12.76% (95% confidence interval 10.30– 15.23), based on 15 eligible articles. A high degree of heterogeneity was observed between studies and between types of infection. Irek et al (2018) presents additional results for 35 studies in Africa, including 13 from Ethiopia, 2 Kenya, 3 Tanzania and 2 Uganda. These studies and further searches revealed several additional studies from the 9 countries. Other reviews that covered studies from Africa include Nejad et al (2011) and Allegranzi et al (2011). All gathered studies are presented in Table 5. Some studies examined only surgical site infections, while others only captured neonatal infections. Estimates that report culture-confirmed infections could be a significant underestimate of the actual HAI rates; hence studies that report these are noted in column 2. Almost all studies in Table 5 are single site studies, i.e., one hospital or health center, and hence are not nationally representative.

Table 5. HAI rates collected from studies conducted in nine countries

Country	Prevalence	Context	Reference
Angola	-	-	-
Congo, Dem. Rep.	64.9%	Teaching hospital in Congo	Ngolet et al, 2021
	17.5%	Maternity hospitals in Mbujimayi	Bukasa et al, 2018
Ethiopia	17%	Systematic review of 18 studies	Alemu et al (2020)
	2% to 82% by infection[1]	Range provided from 13 studies	Irek et al, 2018
	19%	One tertiary hospital	Ali et al, 2018
	15%	Two teaching hospitals	Yallew et al (2016, 2017)
	12.7%	Pediatric patients	Sahiledengle et al (2020)
	3.5% (SSI)	One teaching hospital	Amare et al, 2011
Kenya	2.6% culture-confirmed	One private hospital	Patil et al, 2022
	7.0% (SSI)	One teaching hospital	Dinda et al, 2013
Madagascar	19.6% (NN) of which 1.5% culture-confirmed	Neonates - births in 3 districts 2012-2018	Huynh et al, 2021
Mozambique	-	-	-
Sudan	25.2% (SSI)	One State	Ahmed, 2012
	9% (SSI)	One teaching Hospital	Elbur et al, 2012
	14.2%[2]	Emergency hospital setting	Spagnolello et al, 2022
Tanzania	14.6% (SSI)	Two hospitals	Moremi et al, 2017
	35.6% (SSI)	National hospital	Akoko et al, 2012
	26% (SSI)	One medical center	Mawalla et al, 2011
	14.8%	One tertiary hospital	Gosling et al, 2003
	10.9% (SSI)	One hospital	Bayadorj et al, 2023
Uganda	28%	One large hospital	Greco & Magombe (2010)
	10% (SSI)	National hospital	Seni et al, 2013

[1] BSI (range of 10% to 42%), SSI (2% to 75%), UTI (7% to 53%), VAP (19%), GIT (4%) and SST (4% to 83%)
[2] Varies by medical patients 25.6% and surgical patients 12.4%. Key: SSI – surgical site infection; NN - neonatal

Abubakar et al (2022) found from the 15 Africa studies that surgical site infection was the most common HAI and accounted for 41.6% of all HAIs, followed by bloodstream infection and respiratory tract infections/ pneumonia. The highest rates were found in the ICU (25.2%–100%), followed by neonatal ICU/ward (7.0%–53.6%) and pediatric medical ward (2.7%–33.0%). The prevalence of HAIs in Eastern and Southern Africa region ranged between 11.4%–28.0% and 7.6%–13.5%, respectively.

Based on this evidence, it is appropriate to use the pooled estimates reported in the meta-analysis by Abubakar et al (2022), unless a meta-analysis has been conducted in a single country with sufficient studies informing it. Hence, for eight countries the HAI rate of 12.76% is used, while for Ethiopia the meta-analysis generated HAI rate of 17%. In sensitivity analysis, lower and higher values of half and double the baseline rate are used.

2. Proportion of HAIs that are antimicrobial resistant (AMR)

Harant (2022) assesses the transparency and accountability of national action plans on antimicrobial resistance in 15 African countries, including Ethiopia, Kenya, Tanzania and Uganda. In country responses, Ethiopia and Kenya have full AMR surveillance, while Kenya and Tanzania have partial surveillance. WHO (2020b) also reports on Madagascar, Mozambique, and Sudan. WHO's global report gives global rates of AMR without disaggregation by region or by country.

Systematic reviews of antimicrobial drug resistance in Sub-Saharan Africa show that antimicrobial resistance varies widely for different first- and second-line drugs and across geographies from 0% to over 80% (Leopold et al, 2014; Tadesse et al, 2017; Kariuki et al, 2021). Annex 2 provides details of these are other studies.

Murray et al (2022) report a systematic analysis of the global burden of bacterial antimicrobial resistance in 2019 and produce modelled estimates for resistance of several important pathogens to frontline drugs. The following data extracted focus on the nine countries in the study for selected frontline drugs:

- Meticillin-resistant Staphylococcus aureus is 10%-30% in most of the 9 countries, and 30%-40% in Ethiopia and 50%-60% in Sudan.
- Isoniazid and rifampicin co-resistant (excluding XDR) Mycobacterium tuberculosis is <5% for all of Africa.
- Third-generation cephalosporin-resistant Escherichia coli is 20%-40% in most of the 9 countries, and 40%-50% in Kenya and Uganda, 50%-60% in Ethiopia and 60%-70% in Sudan.
- Carbapenem-resistant Acinetobacter baumannii is variable across the 9 countries: <5% in Uganda, 10%-40% in most of the 9 countries, 40%-50% in Tanzania and Kenya, and 60%-70% in Sudan.
- Fluoroquinolone-resistant Escherichia coli is 20%-30% in Tanzania and Mozambique, 30%-40% in Angola and Kenya, 40%-50% in DRC, Madagascar and Uganda, and 50%-60% in Ethiopia and Sudan.
- Carbapenem-resistant Klebsiella pneumoniae is <5% in most of the 9 countries, 5%-10% in Sudan and 10%-20% in Ethiopia.
- Third-generation cephalosporin-resistant Klebsiella pneumoniae is >50% in all countries, and >80% in Ethiopia, Mozambique, and Sudan.

Adding to these global and multi-country systematic studies are reviews from the nine countries, again showing wide variation in resistance between different drugs (see Annex 2).

In conclusion, the evidence presented above and in Annex 1 indicates significant variation in AMR rates across different bacteria/viruses, across different first line drugs and across different countries and sub-regions. However, given that the analysis is not conducted by different types of HAI, an average rate is needed for the present study. Rates of AMR are seen below 50%, well above 50%, and also around 50%. Hence, in the base case analysis, an average rate of 50% AMR is used. The sensitivity analysis uses alternative AMR rates of 25% and 75%.

3. Annual hospital admissions

In most studies reporting HAI, rates are typically expressed as number of HAIs as a proportion of hospital admissions. Hence, this present study estimates the total HAIs in each country by multiplying the average HAI rate by the total number of hospital admissions in the latest year of data. Data from national statistical reports have been provided for Ethiopia, Kenya, Mozambique, Tanzania and Uganda, mainly relating to 2022 data. These data are presented in Table 6. For countries that did not report recent health sector statistics the number of hospital admissions per year is estimated using an average of 4 inpatient admissions per 100 population.

Table 6. Estimated number of HAIs based on HAI rate and hospital admissions

Variable	Angola	Congo, Dem. Rep.	Ethiopia	Kenya	Madagascar	Mozambique	Sudan	Tanzania	Uganda
HAI rate (% of admissions)	12.0%	12.0%	17.0%	12.0%	12.0%	12.0%	12.0%	12.0%	12.0%
Total inpatients per year	1,779,400	2,760,000	2,976,000	3,200,000	888,000	3,607,172	1,874,960	1,630,442	2,069,310
Estimated number of HAIs	213,528	331,200	505,920	384,000	106,560	432,861	224,995	195,653	248,317
AMR rate (% of HAIs)	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%
Estimated number of AMR infections	106,764	165,600	252,960	192,000	53,280	216,430	112,498	97,827	124,159

Note: Figures in red are estimated based on 4 admissions per 100 population.

For more detailed future analysis, breakdowns between different hospital wards would be possible if specific HAI rates are available. In Kenya, for example, admissions data are commonly provided by hospital level (HC III level, General Hospitals, HC IV, and Regional Referral Hospitals), by region, by age category (typically under five years of age and over five years of age), and by cause.

4. Average hospital cost per day

Recently, a cost categorization of HAI and AMR has been comprehensively provided by Morel et al (2020). However, their framework contains a large number of variables and there are no reports yet of studies that have applied their framework.

More than ten years ago, a review of economic studies that assessed the costs of illness (18 studies) and the cost-effectiveness of interventions (12 studies) for patient safety was reported by de Rezende et al (2012). All studies were from OECD countries. More recently, a systematic review conducted by Serra-Burriel et al (2020) of multi-drug resistant HAIs reported 20 studies (19 OECD countries and China) that estimated the additional costs of AMR. Across the 20 studies identified by Serra-Burriel et al, the average increase in cost was 33%. This increase is a combination of increase in intensity of treatment (e.g., different drugs and more laboratory tests) and increase in hospital length of stay. The former accounted for 6% of the increased cost and the latter 27% of the increased cost. However, none of these studies were from Africa.

Epeh and Fenny (2022) report a review of HAI medical costs in Africa, finding 13 publications from 10 African countries. There was significant heterogeneity across the studies in the additional cost and additional length of stay due to HAI. One study from DRC that was reviewed by Epeh and Fenny (2022) – estimating a cost per HAI of US$10.2 (Bukasa et al, 2018) – was given a low-quality rating based on the statistical methods used.

Due to lack of published data available on the costs of treating HAIs, it is necessary to construct the cost based on available cost datasets on cost per hospital bed day from studies conducted by IHME (2014, 2015). This is shown in Table 7, and is done by adjusting unit costs in local currency units in the year of cost data (2010) to the year of this present study (2022) using the GDP deflator, and then applying the PPP exchange rate conversion for 2022 to convert to US dollars in the year 2022.

Table 7. Cost per bed day in US$ in 2022

Country	Health center	District hospital	Higher hospital
Angola	49.5	48.1	183.8
Congo, Dem. Rep.	7.0	11.1	20.7
Ethiopia	11.2	17.8	33.1
Kenya	55.6	54.1	206.4
Madagascar	6.1	9.6	17.9
Mozambique	6.0	9.4	17.6
Sudan	9.1	14.4	26.9
Tanzania	13.4	21.1	39.4
Uganda	10.7	17.0	31.7

Source: IHME (2014) for DRC, Ethiopia, Madagascar, Mozambique, Sudan and Tanzania; and IHME (2015) for Kenya and Angola.

The estimates in Table 7 are compared with available cost studies from the nine countries. Aerts et al (2022) estimate the costs of neonatal admission for acute bacterial sepsis in Mozambique and South Africa. In Mozambique, the mean hospitalization cost per neonate was I$308 or US$114, and the median cost per neonate was I$275 or US$101.7. Based on the length of stay (mean 16 days, median 15 days), the cost per day was I$19.25 or US$7.1 (mean) and I$18.33 or US$6.8 (median). These unit costs are similar to some countries estimates for health center unit costs in Table 7. Food and accommodation at the hospital are provided to caregivers without charge, so the main direct costs were transportation expenses, which was I$9.58 in Mozambique. The study from DRC had a cost per HAI of US$10.8 (Bukasa et al, 2018).

5. Cost of drugs, supplies and laboratory tests

In addition to the cost of a bed day is the cost of medications, supplies, and laboratory tests to properly treat an infection.

The estimation of the drug costs of HAI in this study is complicated by the fact that information is missing or complicated to collect on (a) what infections account for the majority of infections in each country; (b) the age profile of patients (infants, children, adults); (c) the dosage and form of medication given; and (d) what is the unit cost of each of the first line drugs. In addition, the laboratory costs will depend on what laboratory tests are available at each level of care, the national standard procedures and the extent to which these are followed by medical staff. Hence, it is necessary to extrapolate these costs from the best available evidence from available study (-ies) that represent other countries.

None of the studies presented in the introduction section on the costs of inaction on AMR provided medical costs. Salman et al (2020) conduct a systematic review on the impact of multi-drug resistant bacteria on economic and clinical outcomes of healthcare-associated infections in adults, with most studies from USA and only one study from Africa (Algeria). Hence, it is necessary to draw on the published literature and online data sources. However, very few studies are available from Africa on the costs of treating HAIs and AMR.

Given the present study estimated the costs of treating HAIs at different levels of care, African studies were sources and matched to each level of care (see Table 8).

Aerts et al (2022) estimated the costs of neonatal admission for acute bacterial sepsis in a district hospital in Mozambique. The total medication costs are I$47.9 or US$17.7 and total laboratory costs are I$114 or US$42.2. In case of the latter, the majority are lumbar puncture and CSF test. If only blood culture, urine culture, full blood count test and blood glucose test are included, it is lower at I$34.5 or US$12.75. Hence the drug costs (US$17.7) and laboratory costs (US$12.75) were extrapolated to all other 8 countries at PPPs to represent the health center level.

Gidey et al (2023) compare the cost of treating HAI versus non-HAI patients in Ethiopia, and find an additional US$6.03 for procedures and investigations, US$4.72 more for hospital bed and US$47.2 more for drugs. Hence, the non-bed cost adds up to US$53.2 extra. These costs were extrapolated to the other 8 countries at PPPs to represent the district hospital level.

Boucoum et al (2019) estimate the costs of treating surgical site infections in a teaching hospital in Mali at FCFA 119,837 in 2016, which was updated to 2022 prices and converted to costs in the 9 study countries using PPP conversion.

One study compared the median prices of selected antibiotics in DRC and Cameroon with the international reference price (Schäferman et al, 2020), and found that, on average, the drugs were 2.2 and 5.7 times more expensive in these countries, respectively. For DRC, for the drugs mentioned above in the HAI rate section, it varied from 1.7 times for Ciprofloxacin to 4.6 times for Amoxicillin/Clavulanic. To pay for the latter, a patient would need to work 10 days of wages at the minimum wage.

In Ghana, Otieku et al (2023) found that having an HAI (non-AMR) increased drug cost by 9% and increased laboratory cost by 85%. However, no monetary cost figures are provided.

Table 8. Drug and laboratory costs for treating HAIs

Country	Drugs[1]	Laboratory[1]	Total[1]	High cost scenario[2]
Angola	$21.0	$15.1	$36.1	$86.6
Congo, Dem. Rep.	$22.8	$16.4	$39.2	$94.1
Ethiopia	$12.9	$9.3	$22.2	$53.3
Kenya	$17.6	$12.7	$30.2	$72.5
Madagascar	$28.5	$20.5	$49.0	$117.6
Mozambique	$17.7	$12.8	$30.5	$73.0
Sudan	$6.8	$4.9	$11.8	$28.2
Tanzania	$18.1	$13.1	$31.2	$74.8
Uganda	$15.7	$11.3	$26.9	$64.6

Sources: [1] Aerts et al (2022) for Mozambique, converted to other countries using PPP. [2] Gidey et al (2023) for Ethiopia in the high cost scenario

The estimation of the drug costs of AMR in this study is complicated by the same factors as for HAI (a. through d. above), in addition to (e) whether first line drugs were attempted before switching to second- or third-line drugs; (f) which second and third line drugs are used; and (g) the unit cost of the second and third line drugs. Also, the additional laboratory costs will depend on what laboratory tests are required to successfully diagnose and monitor antimicrobial resistance infections.

In Ghana, Otieku et al (2023) found that an AMR infection (compared to HAI without AMR) increased drug cost by 30% and increased laboratory cost by 42%.

Due to lack of data on these variables to estimate the costs of treating infections with AMR, it is assumed that the costs will be double the costs of treating HAI without AMR.

6. Additional length of stay

Manoukian et al (2018) conducted a systematic review and meta-analysis of the impact of healthcare-associated infections on length of stay. They included 36 studies in the quantitative analysis. There is considerable variability in the estimates of excess days due to HAI, with a range of 1.2 to 26.4 days. Studies used a variety of statistical methods, some being more accurate than others. Still the majority of studies use time-fixed method, which risks overestimating the excess length of stay (De Angelis et al, 2010). Based on Manoukian et al (2018), bloodstream infections cause an average excess days due to HAI ranging from 2.7 days for regression technique to 15.9 days for group comparison, while for gastrointestinal infection caused by Clostridium difficile averages range from 2.3 excess days for multistate modeling to 14.4 excess days for regression technique. No overall average is provided by the study across statistical techniques and across infections.

Three studies were found from the nine countries, or neighboring countries. In Ethiopia, Gidey et al (2023) found average length of stay (ALOS) 8.3 days longer among patients with HAI than non-HAI patients (18.85 vs 10.59 days). Also from Ethiopia, Sahiledengle et al (2020) found ALOS was 11.5 days for pediatric admissions with HAI compared to 6.5 days for non-HAI, giving an addition ALOS of 5 days. In Tanzania, the mean postoperative hospital stay was 5.4 days for uninfected patients compared with 13 days for those with surgical site infection

(Eriksen et al, 2003). In one hospital in Rwanda, Sutherland et al (2019) found that the mean length of stay of 25.5 days for patients with HAI but not AMR compared with 21.9 days for those without HAI. Hence, an HAI increased ALOS by 3.6 days. In Ghana, the ALOS was 3 days longer between the HAI (non-AMR) group and the control group (Otieku et al, 2023). In a meta-analysis of cost impacts of HAIs, Karagiannidou et al (2020) present studies from 3 African countries. In Kenya, HAIs led to additional attributable length of stay of 10.1 days (Aiken et al, 2011); in South Africa, 9 days (Dramowski et al, 2016); and Algeria, 9.2 days (Atif et al, 2008).

By aggregating estimates provided in Manoukian et al (2018) from the different methods and drawing on the anecdotal evidence from Africa, a conservative estimate is that non-resistant HAI leads to an average excess length of stay of at least 5 days. This compares with an overall ALOS in government facilities in Kenya is 3.4 days in 2021/2, and in Uganda the ALOS is 4 days 2019/20.

AMR will lead to an even longer length of stay than with the HAI treatable with first line drugs. The available literature is mainly from developed countries. A systematic review conducted by Serra-Burriel et al (2020) of multi-drug resistant HAIs found 20 studies (19 OECD countries and China) with an average of 27% increase in hospital length of stay. Several studies in used in the meta-analysis of Manoukian et al (2018) compared patients with resistant versus non-resistant infections. Butler et al (2010) used 3 different statistical techniques to compare excess length of stay from vancomycin-resistant versus Vancomycin-susceptible enterococci. Their analysis revealed different results: for group comparison ALOS was 4.6 days more for resistant strains, while for the matching methods it was 1.3 days and for regression it was 1.1 days. Other studies found patients with resistant bacteria stayed 5 days longer (Riu et al, 2016), 1.2 days longer (de Kraker et al, 2011), 7.4 days longer (Barnett et al, 2013), and 7.2 days longer (Stewardson et al, 2013). Stewardson et al (2016) found 3.4 days longer for patients with third-generation cephalosporin resistant Enterobacteriaceae, and 1.8 days for patients with methicillin-resistant Staphylococcus aureus. In one hospital in Rwanda, Sutherland et al (2019) found that that AMR lead to 14.5 excess days of hospital stay compared with HAI without AMR. In Ghana, the ALOS was 4.9 days longer between the AMR group and the HAI group (Otieku et al, 2023).

Drawing on these studies, a conservative estimate is that AMR leads to an average excess length of stay of at least 5 days over and above the 5 excess days for the HAI.

7. Additional recovery time

Time lost from productive activities will be a minimum of the extra time spent in a healthcare facility due to the HAI. For patients that have had HAI, especially those with AMR, the time away from productive activities will be greater than the additional time they spent in hospital. It is assumed that an additional 2 days is required, both for the patient and the caregiver.

8. Value of time lost

This study takes a societal perspective and includes the loss in productive value for working adults and the opportunity cost of time for children and non-working adults. For working adults, the value is conservatively approximated by using the value-added per worker in agriculture, forestry and fishing (World Bank statistics, using 2021 values for most countries). The opportunity cost of time for children and non-working adults is approximated using 30%

of the GDP per capita (valued at a daily value). Sensitivity analyses uses the value-added in industry for working adults, which is significantly higher than for agriculture.

9. Proportion of HAI patients participating in labor force

Participation in the labor force is based on three variables: whether the patient is of working age, whether a patient of working age is active in the labor force, and the gender of the inpatient. This analysis includes not only patients but also their caregivers, who will lose a similar amount of time from their work. The proportion of HAIs suffered by children is assumed to be 40% which is based on data from Kenya where under five children account for 38% of inpatient admissions. The proportion of women is assumed to be 65% compared to men (35%) due to the contribution of maternal conditions to hospital admissions, also based on data from Kenya. For adults, not all will be participating in the labor force. Female and male workforce participation is taken from the World Bank statistics for each country.

10. HAI case fatality rate

The mortality of patients that suffer an HAI is higher than those that do not suffer an HAI, even in developed countries with the best medical systems. From a long-term follow-up study in Norway, for example, patients with HAIs were 40% more likely to die within 1 year relative to those without HAIs (Koch et al, 2015). Evidence gathered by the American Thoracic Society suggests the mortality related to the healthcare-associated pneumonia or "attributable mortality" has been estimated to be between 33% and 50% (American Thoracic Society, 2005). There are only a few studies from Africa. An exploratory literature review with a focus on the nine countries of the present study found seven studies, shown in Table 9. Two studies presented case fatality of only HAI patients, while five compared HAI and non-HAI patients. Differences ranged from 4.2% to 14.6%, with two studies from Ethiopia with a difference of 6.9%. Therefore, in the baseline analysis, the rate of 6.9% is used for all the countries. In sensitivity analysis, a low rate of 4% and a high rate of 15% are used.

Table 9. African studies with estimates of mortality rates from HAI

Country	Context	Case fatality rate			Implied excess CFR (over baseline)		Reference
		HAI (all)	AMR	Non-HAI, non-AMR	HAI (all)	AMR	
Benin	39 hospitals	22%		7.4%	14.6%		Ahoyo et al, 2012
Congo, Dem. Rep.	1 teaching hospital	10%		-	-		Ngolet et al (2021)
Ethiopia	1 hospital	10.8%		3.9%	6.9%		Taye, 2005
Ethiopia	1 specialized hospital	14.7%		7.8%	6.9%		Gidey et al, 2023
Ethiopia	1 teaching hospital	7.5%		3.3%	4.2%		Ali et al, 2018
Kenya	1 hospital (children)	14.6%		-	-		Patil et al, 2022
Sudan	1 emergency hospital	10.3%		2.1%	8.2%		Spagnolello et al, 2022

Patients with an infection with antimicrobial resistance have been shown to have a higher fatality rate than those with a non-AMR healthcare-associated infection. A systematic review conducted by Serra-Burriel et al (2020) of multi-drug resistant HAIs found 20 studies (19 OECD countries and China) with a 61% increase in excess mortality due to AMR. However, while deaths due to AMR in Africa are known, the marginal impact of AMR on the case fatality rate of an HAI is little known. Due to the seriousness of AMR and the expense and poor supply of second and third-line drugs in Africa, it is assumed that twice the number of patients with AMR die compared to those with HAI that is not AMR, i.e., 13.8%. This number is supported by Kariuki et al (2021) who conducted a later review for Sub-Saharan Africa. Drawing on Murray et al (2022), they show that 27% of deaths from an infection are associated with AMR and 6.5% are attributed to AMR.

11. Value of a premature death

The value of premature death has been widely evaluated in OECD countries, and less so in Africa. Saluja et al (2020) conduct an economic modeling study of the impact of physician migration on mortality in low and middle-income countries. Drawing on the recommendations by Robinson et al (2019), they use a baseline value-of-a-statistical life (VSL) of $9.4 million with a base GNI per capita PPP value of $57,900, and an income elasticity (IE) of 1.5, and extrapolate the VSL to developing countries. An IE above 1.0 implies people are willing to spend a lower proportion of their income on mortality risk reduction in lower income settings. More recently, Banzhaf (2022) conducted a meta-analysis of meta-analyses for VSL studies in the USA, and estimates the VSL to be US$8 million in 2019, with a 90% confidence interval of $2.4 million–$14.0 million. In this study, the latest value from Banzhaf (2022) of US$8 million is used to convert values to the nine African countries. In the baseline, an IE of 1.5 is used, while an IE value of 1.2 is used in sensitivity analysis. VSL used are shown in Table 10.

Table 10. VSL values at different income elasticities

Income elasticities	Angola	Congo, Dem. Rep.	Ethiopia	Kenya	Madagascar	Mozambique	Sudan	Tanzania	Uganda
IE = 1.5	$32,532	$5,224	$10,604	$35,782	$4,214	$4,113	$7,773	$13,733	$9,907
IE = 1.2	$97,828	$22,648	$39,902	$105,572	$19,072	$18,706	$31,123	$49,070	$37,789
IE = 1.0	$203,814	$60,216	$96,533	$217,172	$52,180	$51,345	$78,478	$114,691	$92,254

Other ways of valuing human life include the human capital approach. This leads to different values depending on the age at death and the life expectancy. In the absence of data on age profile of patients dying, it is difficult to use the HCA in this study. Also, the value of a disability-adjusted life-year is also estimated and used to value premature death. For example, in Kenya, a DALY value has been estimated at I$ 4,918 in 2019 (Kirigia and Kubai, 2023). For this it is also necessary to know age profiles of patients dying to estimate the number of DALYs lost from HAIs. These data are not available.

Annex 2. Rates of AMR in Africa

Leopold et al (2014) conduct a systematic review of antimicrobial drug resistance among clinically relevant bacterial isolates in Sub-Saharan Africa. Seven years later, Kariuki et al (2021) conduct a review for Sub-Saharan Africa. Results from both reviews show that drug resistance varies widely for first- and second-line drugs across geographies and for different types of healthcare associated infection.

Leopold et al (2014) present results separately by African region, finding for Eastern Africa that the median prevalence (MP) of resistance to chloramphenicol in Enterobacteriaceae ranged between 31.0% and 94.2%, while MP of resistance to third-generation cephalosporins ranged between 0.0% and 46.5%. MP of resistance to nalidixic acid in Salmonella enterica Typhi ranged between 15.4% and 43.2%. However, as the studies presented by Leopold et al are at least 10 years old, it is likely that the results underestimate the current AMR rates in Eastern and Southern Africa. The study only provides reported ranges and does not attempt to estimate an average rate of AMR.

Kariuki et al (2021) focused on key enteric infectious diseases of public health significance in the Sub-Saharan Africa region and found different pathogens have varying rates of resistance to different antimicrobial agents, and with regional variation. In Tanzania, resistance of E Coli to cotrimoxazole and ampicillin was above 80%, and in Ethiopia was above 60%, while in Kenya resistance to tetracycline and ampicillin was above 80% and to cotrimoxazole was above 60%. In Mozambique, resistance to nalidixic acid and ampicillin against vibrio Cholera was 100%, and in Kenya above 80%. In Mozambique, resistance to nalidixic acid against vibrio Cholera was >50%, and to ampicillin was 100%. In the region, resistance to Salmonella enterica Serotype Typhi Isolates was above 70% in Kenya for tetracycline, cotrimoxazole, chloramphenicol and ampicillin; in Uganda above 80% for tetracycline and chloramphenicol; in Ethiopia above 60% for most drugs; and in DRC 55% for chloramphenicol and 70% for ampicillin. In Kenya and Mozambique, resistance was above 60% for many drugs against clinical Salmonella enterica. A study of women with postpartum fever in Uganda found that among 25 blood and urine cultures with Gram-negative isolates, 80% were multi-drug resistant including cefepime-resistant (Bebell et al, 2017).

Tadesse et al (2017) conduct a systematic review of AMR in Africa, including a total of 144 publications covering more than half of African countries. Penicillin resistance in Streptococcus pneumoniae averaged 26.7% from 14 studies. 34.0% of Haemophilus influenza isolates were resistant to amoxicillin. Resistance of Escherichia coli to amoxicillin, trimethoprim and gentamicin was 88.1%, 80.7% and 29.8% respectively. Ciprofloxacin resistance in Salmonella Typhi was rare. Carbapenem resistance was common in Acinetobacter spp. and Pseudomonas aeruginosa but uncommon in Enterobacteriaceae.

Browne et al (2020) reported during the latest period of data (2010-2014) that the pooled prevalence of multidrug resistant S. Typhi was 36% in Central SSA and 59% in Eastern SSA, while fluoroquinolone non-susceptibility (FQNS) was 37% in Central SSA and 16% in Eastern SSA. Murray et al (2022) provide a global picture of AMR rates with country rates across SSA, reported in Annex 1 section 2.

Adding to these global and multi-country systematic studies are reviews from the nine countries. Berhe et al (2021) conduct a systematic review of AMR studies in Ethiopia, identifying 131 qualifying studies. They conclude that, overall, there is a high prevalence of antimicrobial resistance in Ethiopia. 45% of S. aureus and around 20% of the Gram-negative organisms were resistant to cefazoline and ciprofloxacin. Amoxicillin, ceftriaxone, and penicillin G showed 88%, 46% and 32% resistance, respectively. All the causative agents of sepsis showed high levels of resistance to ampicillin (68%), gentamicin (52%), and ceftriaxone (35%). E. coli, K. pneumoniae and P. aeruginosa were the most common Gram-negative pathogens resistant to key antimicrobial agents described in the national standard treatment guideline and were associated with diverse clinical conditions: urinary tract infections, diarrhea, surgical site infections, pneumonia, ocular infections, and middle ear infections. In Ethiopia, Amare et al (2011) report the prevalence of methicillin resistant S. aureus and Staphylococcus was 34.6% and 77.3%, respectively.

In Kenya, Barasa et al (2015) found highest resistance of Staphylococcus aureus isolates to ampicillin (75%), followed by amoxycillin/clavulanic acid (15%), cefuroxime (15%), and cefotaxime (10%). Klebsiella species isolated showed highest resistance to amoxycillin/clavulanic acid (43%), followed by cefuroxime (21%), gentamicin (14%), imipenem (7%), and meropenem (0%).

In Madagascar, Huynh et al (2018) found that, among neonatal infections, there were 11 samples with gram-negative rods that could be tested for antimicrobial drug susceptibility, more than half showed resistance to cefotaxime (6/10) and more than one-third were resistant to gentamicin (4/10) and ciprofloxacin (4/11).

In Mozambique, Kenga et al (2021) reported that nearly 70% of *Staphylococcus Aureus* were methicillin-resistant and roughly 50% of *Klebsiella* had ESBL production.

In Sudan, in 76 patients, gram negative bacteria were for the following: Klebsiella pneumoniae (27.6%), pseudomonas (7.9%), S pyogenes (2.6%), Escherichia coli (1.3%), S auerueus (1.3%) and candida (1.3%) (Ahmed et al, 2021). For *Klebsiela Pneumonia*, MDR was observed in 80% of 86 isolates in the capital city, with 35 isolates (41%) confirmed carbapenem-resistant (Osman et al, 2021).

In Tanzania, Mawalla et al (2011), Staphylococcus aureus was the predominant organism of which 19% were multi-drug resistant.

In Uganda, Anguzu et al (2007) found resistance to ampicillin, amoxycillin and chloramphenicol for surgical site infections. Staphylococcus aureus was most resistant to erythromycin (56.2%) and ampicillin (97%), while being less resistant to gentamicin (13%), ciprofloxacin (31%) and methicillin (25%). Most of the gram-negative bacteria isolated (Coliforms, P.aeruginosa, E.coli, Proteus mirabilis, and Klebsiella pneumoniae) were sensitive to Ciprofloxacin, Gentamicin and Ceftazidime but resistant to Ampicillin, Amoxycillin and Chloramphenicol. Methicillin-resistant Staphylococcus aureus (MRSA) strains formed 25% of this species. Pseudomonas aeruginosa was most resistant to ciprofloxacin (57.2%) and less resistant to gentamicin (13%) and ceftazidime (14%).

In Uganda, Seni et al (2013) report that more than 75% of Enterobacteriaceae were found to be resistant and 37.5% of *S. aureus* were Methicillin resistant *S. aureus* (MRSA). MDR occurred in 78.3% (238/304) of the isolates. Amikacin and imepenem showed excellent performance except that they remain expensive drugs in Uganda.

In conclusion, the evidence presented above indicates significant variation in AMR rates across different bacteria/viruses, across different first line drugs and across different countries and sub-regions. However, given that the analysis is not conducted by different types of HAI, an average rate is needed for the present study. Rates of AMR are seen below 50%, well above 50%, and also around 50%. Hence, in the base case analysis, an average rate of 50% AMR is used. The sensitivity analysis uses alternative AMR rates of 25% and 75%.

Annex 3. WASH, quality of care, and patient satisfaction

A systematic review on patient satisfaction by Bouzid et al (2018) identified 21 papers that had a WASH component. Nine of the 21 studies were found from the focus countries (3 from Uganda, 2 from each of Ethiopia and Tanzania, and 1 from each of Kenya and Madagascar) and are presented in Table 11.

Table 11. Review of literature

Country	Title	Findings	Comment	Source
Ethiopia	Perceived patient satisfaction with inpatient services at one Specialized Hospital	Toilet cleanliness: 18.5% (35/189) were satisfied while 81.5% (154/189) were dissatisfied. 76.6% (145/189) were satisfied with cleanliness of the ward.	Research clearly identified a link between patient outcomes and patient satisfaction scores.	Woldeyohanes et al (2015)
Ethiopia	Assessment of antiretroviral treatment (ART) care service provision in Tigray Region health centers, North Ethiopia	High scores of satisfaction were reported for courtesy and respect 95.80% (684/714) and privacy 93.28% (666/714). Access and cleanliness to latrines were not always assessed. Toilet cleanliness was unsatisfact-ory for 35.32% (243/688).	Adjusted OR for satisfaction was 2.22 (95% CI 1.62 to 6.32) for toilet cleanliness. Measures such as increasing access to ART service, availing clean toilet and ART drugs may further increase client satisfaction. Clean toilets are required especially for HIV/AIDS patients to prevent coinfections.	Tessema and Adnae (2015)
Kenya	Quality of care and contraceptive use in urban Kenya	78.5% of facilities (204/260) have running water.	Facility infrastructure and most aspects of client satisfaction—including privacy issues, amount of information given, waiting time and overall satisfaction—were unrelated to contraceptive use.	Tumlinson et al (2015)
Madag-ascar	Evidence on the reliability of client satisfaction surveys – data from matched facility and household data in Madagascar	An appearance index (mean of binary indicators for dirtiness, humidity damage, decay of walls, floors and ceilings, evidence of insects and condition of toilet facilities) was calculated. The appearance index was 0.84 in household surveys and 0.91 in exit surveys for the same facilities.	The findings suggest that reported satisfaction in exit surveys is biased strongly upward for subjective questions regarding treatment by staff and consultation quality, but not for relatively objective questions about facility condition and supplies.	Glick (2009)
Tanzania	Patients' level of satisfaction on quality of health care at Mwananyamala hospital in Dar es Salaam, Tanzania	422 patients were enrolled. Mean gap score indicated overall dissatisfaction with the quality of care. Respondents were dissatis-fied with general cleanliness (p<0.001), and insufficient and toilets (p<0.001).	The questionnaire has five dimensions (tangibles, reliability, responsiveness, assurance and empathy) to determine patients' level of satisfaction. The gap score is the difference between mean perception and mean expectation scores.	Khamis and Njau (2014)
Uganda	Quality of neonatal healthcare in Kilimanjaro region, northeast Tanzania: learning from mothers' experiences	80 mothers were interviewed from 13 peripheral facilities and 32 from referral hospital. Only 2% discussed issues of hygiene. The state of toilets at referral hospital were as expected for 59% while, in peripheral hospitals 28% were as expected. Toilets were	The most common reasons for primary delays: quality of treatment at the facility 55.1% (27/49) and cost of medical care 32.6% (16/49). Parameters for secondary delays were distance from home (11.1%) and combined distance and transport (7.4%).	Mbwele et al (2013)

Country	Title	Findings	Comment	Source
		worse than expected for 7% and 26%, respectively.		
Uganda	Developing hospital accreditation standards in Uganda	Among accreditation items (1) physical infrastructure and (2) infection control and HCWM are relevant to WASH. 27.5% (11/40) hospitals were not tracking infection rates and 32.5% (13/40) had functional sterilisation equipment.	Good performance was measured in equipment and running water, 24 hours staff calls systems, clinical guidelines and waste segregation. Poor performance was measured in care for the vulnerable, staff living quarters, physician performance reviews, patient satisfaction surveys and sterilising equipment.	Galukande et al (2016)
Uganda	Quality of antenatal care services in eastern Uganda: implications for interventions	74.6% (217/291) respondents rated the ANC service as satisfactory. Infection control was available in 73.4% (11/15) facilities. Cleanliness was dissatisfactory for 4.1% (12/291), fairly satisfactory for 25.8% (75/291) and satisfactory in 70.1% (204/291).	Data collected to gauge infection control: existence of piped running water, water buckets or basins, hand washing soap, disposable hand drying towels, waste bins, sharps containers, disposable latex gloves and disinfection solution. The variables associated with high satisfaction were provider's attitude (87.6%) and examination room privacy (83.5%).	Tetui et al (2012)
Uganda	Challenging logics of complex intervention trials: community perspectives of a health care improvement intervention in rural Uganda	Many health centers lacked running water and electricity. Improvements in antimalarial drug availability were noted but community members were disappointed with the quality of care received. Patients continued to seek care at health centers they considered inadequate.	The intervention targeted malaria control to the exclusion of other diseases or basic infrastructure such as in-patient facilities or clean water. Requests by patients to increase the health workers, expand building space, provide clean water and electricity, in-patient services, and clean toilets were reported.	Okwaro et al (2015)

Source: adapted from Bouzid et al (2018)

Beyond the 9 focus countries, two articles identified in Bouzid et al (2018) review were reviews of low- and middle-income countries. Srivastava et al (2015) concludes that a good physical environment was significant in women's positive assessment of the health facility and maternal care services. In Bangladesh, mothers who rated the availability of services at the facility (a composite of waiting area, drinking water, clean toilet and waiting time) as 'good' were significantly more satisfied with care than those who rated the services as 'poor'. Cleanliness, good housekeeping services and maintenance of hygiene were reported as determinants of satisfaction in Bangladesh, Gambia, Thailand, India and Iran. Interpersonal behavior was the most widely reported determinant, particularly around provider behavior in terms of courtesy and non-abuse.

Gabrysch and Campbell (2009) found that shortcomings in medical care are often coupled with shortcomings in hygiene. Women criticize dirty toilet facilities, lack of water and aseptic practices as well as lack of drugs. Perceived quality of care has an important influence on care seeking behavior. Poor personal and medical quality of care, clash with culture and fear of procedures may decrease use.

Women attending antenatal clinic and choosing to have their child in a healthcare facility find the cleanliness and WASH services as particularly important, especially for prolonged hospitalizations (Srivastava et al, 2015).

Upadhyay et al (2013) used the three delays model to explore the social factors affecting neonatal deaths: delay in deciding to seek care on the part of the individual, family, or both (Delay 1), delay in reaching an adequate health care facility (Delay 2) and delay in receiving adequate care at the health facility (Delay 3). Multiple factors were reported to delay care seeking for newborn illness, although poor WASH or lack of cleanliness were not explicitly mentioned in the reasons.

Endnotes

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[1] More fully: an HAI is a localized or systematic condition resulting from adverse reaction to the presence of infectious agent or its toxins acquired from health care settings that was not incubating or symptomatic at the time of admission to the healthcare facility (Horan et al, 2008).

[2] Systematic reviews of antimicrobial drug resistance in Sub-Saharan Africa show that antimicrobial resistance varies widely for different first- and second-line drugs and across geographies from 0% to over 80% (Leopold et al, 2014; Tadesse et al, 2017; Kariuki et al, 2021). Murray et al (2022) report a systematic analysis of the global burden of bacterial antimicrobial resistance in 2019 and produce modeled estimates for resistance of several important pathogens to frontline drugs. The data extracted from the nine countries in the study are presented in Annex 1 section 2. In conclusion, the evidence presented above and in Annex 2 indicates significant variation in AMR rates across different bacteria/viruses, across different first line drugs and across different countries and sub-regions. However, given that the analysis is not conducted by different types of HAI, an average rate is needed for the present study. Rates of AMR are seen below 50%, well above 50%, and also around 50%. Hence, in the base case analysis, an average rate of 50% AMR is used.

[3] This gave the following total number of inpatient admissions per country in 2022: Angola 1,423,520; DRC 3,680,000; Ethiopia 2,976,000; Kenya 3,188,916; Madagascar 1,184,000; Mozambique 3,607,172; Sudan 1,874,960; Tanzania 2,035,200; and Uganda 3,304,800.

[4] Due to lack of published data available on the total costs of treating HAIs, it is necessary to construct the cost based on the cost per hospital bed day, the additional length of stay due to HAI, and the costs of drugs, procedures and laboratory tests related to the HAI. AMR will also lead to longer length of stay, and additional costs of drugs, procedures and laboratory tests.

[5] The highest quality cost studies for different levels of the health systems were from IHME (2014) for Uganda which was extrapolated using PPP to other countries with GDP per capita below US$1,100 (DRC, Ethiopia, Madagascar, Mozambique, Sudan and Tanzania); and IHME (2015) for Kenya, which was extrapolated using PPP to Angola.

[6] Gidey et al (2023) for Ethiopia, reflecting health center level - converted to each country using PPP.

[7] Aerts et al (2022) for Mozambique, reflecting district hospital level - converted to each country using PPP.

[8] Bocoum et al (2019) for Mali, reflecting referral, tertiary, or teaching hospitals - converted to each country using PPP.

[9] Based on Ghana data, as follows. Fenny et al (2020) found in a teaching hospital additional average length of stay (ALOS) of 4.6 days for patients with SSI. Otieku et al (2023) found ALOS was 3 days longer between the HAI (non-AMR) group and the control group.

[10] Otieku et al (2023) found patients in the AMR cohort stayed approximately 5 more days compared with HAI patients and 8 more days compared with uninfected cohorts.

[11] As follows:

Variable	**Angola**	**Congo, Dem. Rep.**	**Ethiopia**	**Kenya**	**Madag.**	**Mozam.**	**Sudan**	**Tanz.**	**Uganda**
% women employed	37.0%	60.3%	57.6%	62.9%	83.6%	78.1%	28.3%	76.2%	37.4%
% men employed	50.8%	66.8%	79.2%	73.0%	89.2%	80.1%	70.1%	85.0%	57.1%
Daily value-added in agriculture	$8.9	$2.4	$4.6	$10.2	$2.1	$2.6	$22.0	$4.9	$4.3
Daily value-added in industry	$284	$40	$23	$53	$9	$18	$50	$57	$60

[12] An exploratory literature review with a focus on the nine countries of the Hutton et al (2023) study found seven studies. Two studies presented case fatality of only HAI patients, while five compared HAI and non-HAI patients. Differences in case fatality ranged from 4.2% to 14.6%, with two studies from Ethiopia with a difference of 6.9%.

[13] US$8 million VSL value from the USA (Banzhaf, 2022) converted to each country based on GDP per capita differential with the USA and using an income elasticity of 1.5. In sensitivity analysis, an income elasticity of 1.2 was used.

[14] Experts in UNICEF's country offices were surveyed for information regarding the average costs per facility of improving from an absence of WASH and waste services to meeting the JMP's monitoring definitions for basic services. These per facility costs were applied to the current coverage estimate of WHO and UNICEF Joint Monitoring Programme in 2019 to estimate total costs per country, based on which an average was estimated across the 47 countries.

[15] Given that the cost data presented in Chaitkin et al (2022) did not present country data following a request for anonymity from some countries sampled, this present study does not present country cost information.

[16] This is excluding Angola, Kenya and the United Republic of Tanzania.

[17] Inclusion of costs for middle-income countries may increase cost per capita.

[18] Indeed, patient satisfaction is an outcome of the healthcare process itself, determined by the quality of the infrastructure and associated behaviors, including cleanliness, crowding and availability of WASH facilities. These factors also determine future health seeking behavior, not only of patients themselves but of others that hear of bad or good experiences with health care. A 2019 survey of over 1 million women and girls in 114 countries found that of the top demands for quality reproductive and maternal health care, respectful and dignified maternity care was the most cited need, followed by WASH services and facilities (White Ribbon Alliance, 2019).