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Priority regions for eliminating open defecation in Africa: implications for antimicrobial resistance

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Abstract

Sanitation, which offers safe and effective methods for waste disposal, is important for development. However, in Africa and other developing regions, the prevalent practice of open defecation (OD) impedes attaining the sustainable development goals (SDGs). This research delves into the analysis of OD in Africa and proposes a three-tier priority system, comprising critical, high, and medium areas, through which developmental endeavours can be targeted. To achieve this, the study utilizes data from demographic and health surveys (DHS) and the World Bank. The rates of OD at country and sub-country/region levels were calculated to define the priority system, and regression analyses were used to determine predictors of OD practice. The findings are that Nigeria, Ethiopia, Niger, the Democratic Republic of Congo, Burkina Faso, and Chad have a high number of people struggling with open defecation. In addition, disparities in access to proper sanitation facilities were identified among impoverished individuals and those residing in rural areas. After adjusting for education and residence, the poorest are 43 times (95% confidence interval 42.443–45.290) more likely to practice open defecation in comparison with the wealthiest. Consequently, wealth index is a pivotal factor in eradicating open toileting. To address this pressing issue in Africa, it is imperative to prioritize evidence-based targeted interventions that concentrate on regions and communities urgently needing improved sanitation infrastructure and programmes. Special attention should be paid to West Africa since many of its communities are in the critical category. Poverty and inequality must be addressed and investments in sanitation infrastructure, behavioural change promotion, and support multistakeholder collaborations should be encouraged. To evaluate OD interventions and monitor health impact, variables such as antimicrobial resistance (AMR) should be included in important health surveys (e.g. DHS). This study is the largest meta-data analyses of OD in Africa detailing drivers and communities that should be prioritised on sanitation interventions.

Keywords Open defecation · Sustainability · Toilet · Health · Health survey · Africa development · Antimicrobial resistance

1 Introduction

The United Nations (UN) recognizes access to clean water, sanitation, and health (WASH) as a human right. Despite progress in improving access to these essential services, billions of people still lack them. According to the UN (2015) and United Nations Development Programme (UNDP) (2021), over 4.5 billion people or over half of the global population lack safe sanitation. Additionally, 946 million people continue to practice open defecation (OD), which is the act of disposing of human waste in open areas rather than using a toilet.

Economic and cultural belief systems drive OD practices (Gauri et al., 2023; Kar & Milward, 2011; Ntaro et al., 2022). Public health officials must understand the complex interactions between socio-economic, behavioural, and environmental factors to combat this practice and develop context-specific strategies (Dandabathula et al., 2019). One successful approach is Community-led Total Sanitation (CLTS), which has contributed to significant progress in the Millennium Development Goals across Asia and Sub-Saharan Africa (UNICEF and WHO, 2015; Zuin et al., 2019). In CLTS, communities appraise and analyse OD, then mobilise people to identify solutions and monitor progress (Kar & Milward, 2011; Kouassi et al., 2023). OD is a threat to human dignity, poses environmental and health risks (Dandabathula et al., 2019) and is linked to a significant number of deaths from cholera and typhoid in developing countries (Akilimali et al., 2023; Mara, 2017).

OD is a degrading, polluting, and dangerous practice that disproportionately affects developing countries, particularly in Asia and Sub-Saharan Africa. 90% of people who engage in OD reside in rural areas of these regions (WHO/UNICEF, 2017; Saleem et al., 2019; UN DESA, 2019; 2021). The United Nations department of economic and social affairs (2021) noted that OD clearly indicates extreme poverty in affected countries. Studies have shown that improved sanitation can reduce the transmission of enteric pathogens and intestinal parasites, decreasing morbidity and mortality, especially in children (Mara, 2017). Therefore, the sustainable development goals (SDGs) offer a holistic solution to the social, health, and environmental challenges posed by OD by maximizing synergies and collaborating to address water and sanitation issues rather than relying on limited individual interventions.

1.1 The sustainability goals on water and sanitation

There has been deliberate effort and interventions since the beginning of this Millennium to end OD to promote good health and a sustainable environment and, therefore, the basis of the target 7C of the Millennium Development Goals (MDGs) relating to sustainable access to safe drinking water and basic sanitation (UNICEF and WHO, 2015; WHO, 2018). SDG 6 aims to expand access to basic water and sanitation services and close the gaps in service quality. The SDG 6 has six outcome-oriented targets but with a total (including sub-targets of 8) of 11 indicators to represent the metrics for tracking the achievement of the targets, of which target 6.2 appears to be a rebirth of the MDG target 7C. Notably, a total of 2.6 billion people gained access to safe water in the MDG regime, and 2.1 billion obtained access to safe sanitation (United Nations, 2015). Despite the success achieved, criticism emerged regarding the ambiguities of the classification "improved and unimproved" as used in the report presented. However, this was subsequently reviewed and addressed by the WHO/UNICEF Joint Monitoring Programme (JMP) 2017 report. This paper does not intend to engage in the dialectics or semantics to argue the operationalisation of these constructs but

to make a case for retrospective understanding, analyses of current status and future thinking to be able to develop robust and pragmatic context-relevant measures that can sever these societies from the vulnerable practice of OD. At the beginning of the millennium, a non-profit organisation, World Toilet Organisation, was formed to draw global attention to the sanitation crisis and established November 19 as world toilet day (WTO, 2021). In less than a decade, the international year of sanitation was commemorated to encourage countries to commit to increasing safe toilet facilities and ending open defecation (UN Water, 2008). The fifteen-year implementation phase of MDGs ended without any country in sub-Saharan Africa achieving target 7C; however, the SGD 6 holds a promise that changes the story.

1.1.1 Clean water and sanitation

The sixth goal of the SDGs is focused on providing access to clean water and sanitation. While an estimated 5.2 billion people had access to safely managed drinking water in 2015, 844 million still lacked basic access. Similarly, while 2.9 billion people had access to safe sanitation in 2015, 2.3 billion people still lacked basic sanitation facilities (UNDP, 2021). These challenges are further compounded by the fact that 892 million people still practice open defecation (CDC, 2022). Target 6.2 is that by 2030, the world should achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying particular attention to the needs of women, girls, and those in vulnerable situations (UNDP, 2021). In addition, the issue of water security, a significant factor in sanitation and a critical resource in the effort to end OD is a priority area in Agenda 2063, the seventh goal of the African Union strategic framework aligns with SDG6 (AU, 2015; 2021). This highlights global and regional efforts to halt many of the problems developing countries face and free them from the constraints of poverty and its manifestations. The essentiality of water implies that it touches every aspect of development and is a critical nexus for nearly every SDG. Recently, the US International Development Association (IDA), through the World Bank, approved a \$700 m credit to Nigeria to pursue the Sustainable Urban and Rural Water Supply, Sanitation, and Hygiene Programme (SURWASH) that will provide 6 million people with basic drinking water services and 1.4 m people access to improved sanitation services with the potential to support 500 communities to achieve open defecation free status (Nasir, 2021).

1.2 Why toilet and burden of open defecation

Toilet is a crucial development amenity since it positively correlates with achieving other SDGs. For instance, a clean and safe toilet enhances educational attainment (SDG4) and reduces gender inequalities (SDG5) (Daniel et al., 2023; Das et al., 2023; Unterhalter et al., 2014). Similarly, investment in sanitation has been reported to generate a quantifiable, positive return on investment with savings on medical costs and increased productivity. The assessment paper established a relationship between sanitation and economic growth (SDG8). It posed that every \$1 invested in basic sanitation yields a return of \$3 (Hutton et al., 2015; UN Water 2023). The more obvious importance of a clean and safe toilet relates to attaining good health and wellbeing. Inadequate drinking water, sanitation, and hygiene are important risk factors, especially in low- and middle-income countries (WHO, 2022). A systematic review of sanitation studies published between 1970 and 2013 indicates that about 280,000 diarrhoea deaths occurred

due to inadequate sanitation with figures increasing yearly (Prüss-Ustün et al., 2014, 2019). OD encourages the transmission of pathogens (such as bacteria and viruses) and parasites (such as nematodes and helminths) which cause damage to human health (Carr, 2001; Dandabathula et al., 2019; Prüss-Ustün et al., 2019). OD also affect production and food safety. Salmonella, usually present in human faeces, negatively affects maize and bean seeds (Singh et al., 2007). In addition, it can also lead to direct and indirect food safety issues. For example, flies and other insects are attracted to faeces. They can carry bacteria from faecal matter to food, leading to contamination. Animals may also be attracted to faeces, which can lead to the contamination of food sources through direct contact or the spread of faeces-borne diseases (Guthami et al., 2017). Open defecation contributes to the contamination of soil and water, and the transmission of diseases (Brooks et al., 2023; Joab et al., 2017; Miranda et al., 2018). A global assessment of faecal exposure found that contamination of water sources by pathogens through faeces is highest in Africa and adds more pressure on the efforts to close the gap on health disparity (Bain et al., 2014). More worrisome is that there are well established evidence showing that antimicrobial resistance (AMR) pathogens developed and spread through open defecation and sub-Saharan Africa has the highest AMR burden (Wellcome Trust et al. 2018; Hendriksen et al., 2019; Murray et al., 2022).

The high population growth rate in Africa, especially in Sub-Saharan, affects attaining an open defecation-free continent (Abebe & Tucho, 2020). A study reported that among 34 Sub-Saharan African countries, only Angola, Ethiopia and Sao Tome and Principe had a $\geq 10\%$ reduction in OD between 2005 and 2010 (Galan et al., 2013). The provision of functioning latrine toilets has been recognised as a cost-effective way to end open defecation. This has been an implementation focus during the MDGs regime (Tyndale-Biscoe et al. 2013; Kipkoech et al., 2023). However, the provision of toilets does not always equate to the end of open defecation (Singh and WSP, 2007; Sinha, 2019). Even when the provision of toilets is assumed to be zero OD, a continental study reported that 13% of the beneficiaries reverse into practising OD after about two years and the same elsewhere in Asia (Tyndale-Biscoe et al., 2013; Augsburg et al., 2022). Financial support, lack of follow-up support, inconvenience, discomfort, sharing with others, maintenance, and repair were identified as reasons for the return to OD or slippage.

1.2.1 Determinants of open defecation

The threat of OD practice called for an understanding its determinants. One of the earliest efforts in WASH is the development of a theoretical framework called FOAM-Focus on Opportunity, Ability and Motivation (Coombes & Devine, 2010; Khare & Suresh, 2021). The framework was designed to support WASH implementers in the development, evaluation, and monitoring of behavioural change. Targeting population is recognised within the 'focus' stand of the framework and well adapted to in understanding the determinant of open defecation. The variables that are linked to OD differ depending on population of studies (Abubakar, 2018). Notwithstanding, the most identified determinants of OD include education, occupation, area of residence, wealth, farming distance from home, weather and seasons, use of substances and alcohol, household size, gut health status and enteric diseases, government policies and investment, geopolitical region, ownership of toileting facilities (Abubakar, 2018; Osumanu et al., 2019; UN Water, 2020; Belay et al., 2022; Ali & Khan, 2023).

1.3 A pan African study on open defecation

The MDGs report states that the proportion of the global rural population practising open defecation has fallen from 38 to 25% between 1990 and 2015 (UN, 2015). However, using a global aggregate, the MDG report masked the contextual realities of African countries. Many African countries are far from the pathway to ending OD. This appears to play down the seriousness of the problem and tackle it head-on within the next SDGs phase. Reports show that most countries lagging in meeting the access to adequate sanitation targets are located in Sub-Saharan Africa (Waage et al., 2010; UNICEF and WHO, 2020). Although there are efforts through policy-driven agendas in continental Africa and at regional levels, for example, the African Union Agenda 2063 and ECOWAS vision 2050 to end open defecation by 2030 under the current SDGs, there is a lack of pragmatic efforts with regards to funding and implementation (NEPAD, 2022; ECOWAS, 2022). Yet, approximately 60 million Nigerians lacked access to basic drinking water services, 80 million lacked improved sanitation, and 167 million lacked a basic handwashing facility. In rural regions, 39% of families lack access to at least basic water supply services. At the same time, only half of this number have access to improved sanitation and about a third practise open defecation. This percentage has remained relatively unchanged since 1990 (Nasir, 2021). In Kenya, its bureau of statistics demonstrates that only 39% of Kenyans use unimproved sanitation facilities (Busienei et al., 2019a, 2019b). There are over 25 African countries with more than 15% of their population practising OD (WHO/UNICEF JMP, 2021), and this is as high as 73% in Niger, 74% in South Sudan and 77% in Eritrea. Studies that synthesize multinational large datasets on OD and capture diverse range of contexts are still lacking. This study aims to evaluate prevalence and sociodemographic drivers of open toileting in Africa and highlights communities in urgent need based on three-tier priority system. These will allow for addressing the contextual realities of African countries and the need for pragmatic and efforts to tackle the persisting OD issue.

2 Methods

2.1 Study population

The study population for this research was primarily drawn from Demographic and Health Survey (DHS) data for African countries. The data collection for DHS was approved by the ethics committee of each host country, consisting of the statistics office/bureau and health ministry (DHS, 2022). Technical support for the survey was given by ICF International Inc. The DHS program surveys are nationally representative. DHS program office in Rockville, Maryland, approved using de-identified datasets from African countries for analysis of water, sanitation, and hygiene.

Data used in this study were available acquired immunodeficiency syndrome (AIDS) indicator survey (AIS), malaria indicator survey (MIS) and demographic and health surveys (DHS). Two hundred and twenty-two health surveys across Africa were checked for sanitation variables. The total sample size is 8,659,881. All these surveys are nationally representative population-based surveys. However, AIS focuses on human immune-deficiency virus/AIDS and related issues, while the MIS focuses on malaria and associated issues, with a sample of about 3,000 households each. The DHS have a larger sample size,

usually 5000–30,000 households. Toileting questions used throughout this study are under household member recode. The latest DHS phase available for a country is chosen as the most recent data available. The same is used to depict the current situation. For instance, Angola has datasets AOPR51FL, AOPR62FL, and AOPR71FL. Still, dataset AOPR71FL is the most recent dataset from this country since it was conducted in phase 7. When MIS, AIS, or DHS datasets are available in the same phase in a country (e.g. Ghana), the standard DHS dataset is used instead since it is more extensive. Where AIS and MIS only are available in the most recent phase, the dataset with a later collection date is chosen (e.g. Mozambique). The total sample size is 8,659,881, the datasets used were sourced from DHS (DHS, 2022). Eastern and Western African surveys have the highest number (Table 1).

2.1.1 Assumptions for 2030 OD projections

To understand the current trend of the top ten African countries practising open defecation based on population, statistics from the World Bank population estimates for the year 2020 were used. Similarly, a 2030 projection on how challenging OD may be in these ten countries made use of the World Bank population projection for the year 2030 (World Bank, 2023).

Table 1 Overview of the dataset used for the thirty nine African countries showing sample size and regions

Country	Sample size	No of Surveys	Country	Sample size	No of Surveys
Central			Eastern		
Angola	129,893	3	Burundi	144,073	3
Cameroon	171,652	4	Comoros	38,631	2
Central Africa Republic	27,992	1	Ethiopia	289,033	4
Chad	165,899	3	Kenya	331,483	6
Republic of Congo	112,562	3	Madagascar	319,088	7
Democratic Republic of Congo	144,071	2	Malawi	373,553	8
Gabon	73,973	2	Mozambique	258,930	6
Sao Tome and Principe	13,430	1	Rwanda	309,542	7
Western			Tanzania	450,922	10
Benin	311,612	5	Uganda	358,252	8
Burkina Faso	284,969	6	Zambia	230,934	5
Cote d'Ivoire	127,768	4	Zimbabwe	186,845	5
The Gambia	52,647	1	Northern		
Ghana	184,836	6	Egypt	619,789	7
Guinea	166,434	4	Morocco	104,007	2
Liberia	147,027	5	Southern		
Mali	342,182	6	Lesotho	125,169	3
Niger	182,768	4	Namibia	142,373	4
Nigeria	627,623	7	South Africa	91,428	2
Senegal	720,890	13	Swaziland (Eswatini)	26,974	2
Sierra Leone	157,170	3			
Togo	113,457	3			

Country and regional grouping 39 African countries in the study are grouped into five sub-regional categories. These categories follow the United Nations M49 standard classification of countries worldwide (UNSD, 1999). The type of data included for each sub-region and country is presented in the supplementary material.

2.1.2 Survey questionnaires, variables and covariates

The DHS program uses standard model questionnaires and a written description of why specific questions have been included. The current and previous versions of questionnaires used for the DHS, MIS, and AIS are open source at DHS Program methodology section. The dependent variable used in this study is 'type of toilet facility' HV205. No facility/outdoor/bush = 31 was used for open defecation. Other values indicate using a type of toilet, covering various flush toilets and latrine/pit toilet options. At the same time, other variables are 'type of place of residence' HV025, 'region/province' HV024, and 'wealth index' HV207. Known underlying factors and determinants that may contribute to open defecation were explored. The determinants probed are poverty, sex, age group, place of residence, and education. These determinants were included as covariates in the analysis.

2.1.3 Regression analysis

Multinomial regression analysis was performed for regions with critical priority regions (Chatterjee & Simonoff, 2013). The dependent variable 'type of toilet' HV205 was recoded using three categories: Flush toilet (values 10–19), Latrine toilet (values 20–29) and No toilet/Open defecation (values 30–31). The independent variables include 'wealth index combined' HV270 as a factor. Covariates are 'highest education level attained' HV106 and 'type of place of residence' HV025.

The equation used for multinomial regression analysis is:

$$\log(k_1) = \alpha_{k_1} + \beta_{k_1,1}X_1 + \beta_{k_1,2}X_2 + \dots + \beta_{k_1,v}X_v$$

...

$$\log(k_n) = \alpha_{k_n} + \beta_{k_n,1}X_1 + \beta_{k_n,2}X_2 + \dots + \beta_{k_n,v}X_v$$

where $\log(k_n)$ is the natural logarithm of class k_n versus the reference class k_0 , X is a set of explanatory variables ($X_1, X_2 \dots X_v$), α_{k_n} is the intercept term for class k_n versus the reference class, and β is the slopes for the classes.

The equation for binomial regression analysis is:

$$P(Y) = \frac{e^{b_0+b_1x_1+b_2x_2+\dots+b_nx_n}}{1 + e^{b_0+b_1x_1+b_2x_2+\dots+b_nx_n}}$$

where P the probability of Y occurring, e is the natural logarithm base, b_0 is the intercept at the y-axis, b_1 is the line gradient, b_n is the regression coefficient of X_n , X_1 is the predictor variable. The minimum variable is two.

2.1.4 Priority categorisation

To see where there is a need for intense sanitation programmes and efforts, regions were classified into three categories:

Critical priority, for geographical locations where the open defecation rate is greater than 80%.

High priority, for geographical locations where the open defecation rate is between 60 and 80%.

Medium priority, for geographical locations where the open defecation rate is between 40% and less than 60%.

2.1.5 Ethics statements

For this study, no ethical approval was needed from individuals or participants because it was a secondary data analysis of de-identified data, originally collected by the DHS Program and generously made available. DHS Program approved the use of the datasets.

3 Results

The estimated rate of open defecation by population revealed that Nigeria (54 million), Ethiopia (43 million) and Niger (15 million) top the table of African countries with the highest number of people practising OD (Table 2). Others include DR Congo, Burkina Faso, Chad, Angola, Madagascar, Kenya, and Cote d'Ivoire. These ten countries could account for about 247 million Africans defecating in the open by 2030 if critical and emergency actions are not taken. The datasets used for analysis were from DHS Program and the World Bank (DHS, 2022; World Bank, 2023).

Analyses of the past DHS datasets indicate that Egypt, Comoros, and Rwanda are historically on the right path to ending open defecation (Table 3). Just only 0.1% of the population of Egypt practices open defecation. Within fourteen years, the country went from a 3.5% rate to 0.1%. Egypt is one of African most feasible countries to end open defecation

Table 2 Top ten African countries practising open defecation based on population

Country	OD rate (%)	Practising OD	Data used	Projection by 2030 under status quo
Nigeria	26.6	54,833,240	DHS 2018	69,951,882
Ethiopia	37.6	43,226,464	DHS 2016	54,498,944
Niger	64.1	15,516,687	DHS 2012	22,336,286
DR Congo	14.7	13,165,467	DHS 2013	17,646,909
Burkina Faso	55.2	11,538,456	MIS 2014	15,127,008
Chad	69.4	11,399,644	DHS 2015	15,052,860
Angola	32.9	10,812,914	DHS 2016	14,750,715
Madagascar	38.5	10,661,035	MIS 2016	13,714,470
Kenya	18.4	9,893,864	DHS 2014	12,226,800
Cote d'Ivoire	35.4	9,337,812	DHS 2012	11,934,402
		190,385,583		247,240,276

Table 3 Countries that historically have <5% open defecation rate

Country	Year of Study	Data	Code	OD rate (%)
Egypt	2000	DHS	EGPR42FL	3.5
	2003	DHS	EGPR4AFL	2.0
	2005	DHS	EGPR51FL	1.6
	2008	DHS	EGPR5AFL	0.5
	2014	DHS	EGPR61FL	0.1
Comoros	1996	DHS	KMPR32FL	0.3
	2012	DHS	KMPR61FL	0.7
Rwanda	2000	DHS	RWPR41FL	2.9
	2005	DHS	RWPR53FL	3.3
	2008	DHS	RWPR5AFL	2.0
	2010	DHS	RWPR61FL	1.0
	2013	MIS	RWPR6QFL	1.7
	2015	DHS	RWPR70FL	2.9
	2017	MIS	RWPR7AFL	1.4
Cameroon	1991	DHS	CMPR22FL	2.1
Burundi	2010	DHS	BUPR61FL	2.6
	2012	MIS	BUPR6HFL	2.2
	2017	DHS	BUPR70FL	1.9
South Africa	2016	DHS	ZAPR71FL	2.6
Gabon	2000	DHS	GAPR41FL	2.7
	2012	DHS	GAPR60FL	2.5
	2012	DHS	GAPR60FL	2.5
Gambia	2013	DHS	GMPR60FL	2.5
Malawi	2014	MIS	MWPR71FL	4.2
	2015	DHS	MWPR7AFL	5.2

by 2030. Historically, nearly Open defecation-free countries include Egypt, Comoros, Rwanda, Burundi, Gabon, Gambia, and South Africa. The datasets were from the DHS Program (DHS, 2022).

Countries that historically have OD rate > 50% are Benin, Ethiopia, Niger, Burkina Faso, Togo, Chad, Namibia, Sao Tome and Principe, Madagascar, Liberia, and Mozambique (Table 4). These countries have always been highly burdened with sanitation challenges. More than half of the population in these countries still has no toilet facilities except for Mozambique (21.7%), Madagascar (38.5%), Liberia (40.5%), and Burkina Faso (42.7%). The datasets were from the Demographic and Health Survey (DHS, 2022).

The sub-national/regional/provincial level burden indicates that it is still high in some African urban areas (Fig. 1). Benin, Chad, Namibia, and Sao Tome and Principe particularly have the challenge of sanitation in their urban centres. Provinces with a critical urban OD rates are *Atacora* (81.9%), and South region (80.9%) in Benin and Sao Tome and Principe, respectively. The high-priority regions are *Ennedi* and *Lac* (Chad), *Karamoja* (Uganda), *Est* (Burkina Faso), and *Ohangwena* (Namibia), with OD rate of 73.1%, 65.0%, 68.1%, 65.0%, and 63.9%, respectively. The thirty-five regions requiring urgent action comprise two critical priority regions, five high-priority regions and 28 medium-priority regions. The datasets were from the Demographic and Health Survey (DHS, 2022).

Table 4 Countries that historically have > 50% open defecation rate

Country	Year of Study	Data	Code	OD rate (%)	Country	Year of Study	Data	Code	OD rate (%)
Benin	1996	DHS	BJPR31FL	76.7	Chad	1997	DHS	TDPR31FL	58.2
	2001	DHS	BJPR41FL	68.3		2004	DHS	TDPR41FL	53.1
	2012	DHS	BJPR61FL	61.8		2014	DHS	TDPR71FL	69.4
Ethiopia	2018	DHS	BJPR71FL	57.9	Namibia	1992	DHS	NMMPR21FL	67.0
	2000	DHS	ETPR41FL	74.0		2000	DHS	NMMPR41FL	51.4
	2005	DHS	ETPR51FL	58.4		2006	DHS	NMMPR52F1	54.8
	2016	DHS	ETPR71FL	37.6		2013	DHS	NMMPR61FL	50.6
	1998	DHS	NIPR31FL	71.8		Sao Tome and Principe	2009	DHS	STPR50FL
2006	DHS	NIPR51FL	68.8	Madagascar	1992		DHS	MDPR21FL	54.5
2012	DHS	NIPR61FL	64.2		1997		DHS	MDPR31FL	58.7
1992	DHS	NIPR22FL	65.1		2011	MIS	MDPR6H	54.9	
Burkina Faso	1993	DHS	BFPR21FL	55.7	2013	MIS	MDPR61FL	53.9	
	1999	DHS	BFPR31FL	70.1	2016	MIS	MDPR71FL	38.5	
	2003	DHS	BFPR44FL	69.3	Liberia	2007	DHS	LBPR51FL	54.1
	2010	DHS	BFPR62FL	63.1		2013	DHS	LBPR6AFL	54.7
	2014	MIS	BFPR71FL	55.2		2016	MIS	LBPR71FL	40.5
	2018	MIS	BFPR7AFL	42.7	Mozambique	1997	DHS	MZPR31FL	53.5
1998	DHS	TGPR31FL	69.7	2018		MIS	MZPR7AFL	21.7	
2014	DHS	TGPR61FL	60.1						
2017	MIS	TGPR71FL	54.0						

Urban communities needing priority interventions

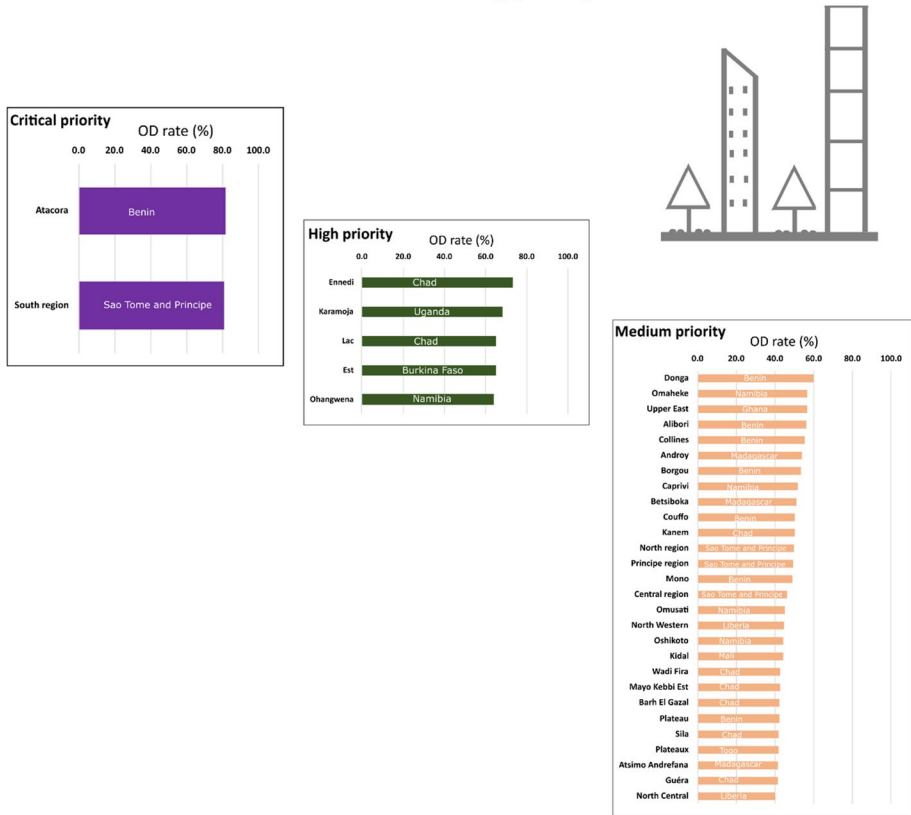


Fig. 1 Urban communities in Africa needing priority interventions against open defecation

Figure 2 indicates that OD is mainly at a critical or high-priority state in rural areas of Africa. The burden at the sub-national level means that Lac (98.7%), Kanem (97.3%), Ouaddaï (96.9%), Batha (92.5%), Barh El Gazai (91.8%), Logone Oriental (80.2%), Borkou/Tibesti (89.8%), Tandjilé (88.9%), Wadi Fira (88.9%), Mandoul (86.2%), Ennedi (85.3%), Mayo Kebbi Est (84.2%), Logone Occidental (80.4%), all in Chad require critical prioritization.

Other regions that need critical rural prioritising are **Angola** (*Benguela, Cunene, Bamibe, Huila, Cuanza Sul*), **Namibia** (*Kavango, Caprivi, Ohangwena, Omusati*), **Madagascar** (*Diana, Atsimo Andrefana, Boeny, Ihorombe*), **Benin** (*Atacora, Borgou*), **Burkina Faso** (*Sahel, Centre-Sud, Centre-Quest*), **Niger** (*Agadez, Dosso, Tahoua, Tillaberi, Zinder, Maradi*), **Cote d'Ivoire** (Centre), **Ethiopia** (*Afar*), and **Ghana** (Northern, Upper East). Similarly, 59 out of 412 sub-national regions in this study have a high OD rate in rural areas (Fig. 2).

Countries with one or more regions with critical open defecation rates by residence are Angola, Benin, Burkina Faso, Chad, Cote d'Ivoire, Ethiopia, Ghana, Madagascar, Namibia, Niger, and Sao Tome and Principe (Table 5). Irrespective of residence, all the Sao Tome and Principe regions have sanitation challenges requiring at least one of the

Rural communities needing priority toilet interventions

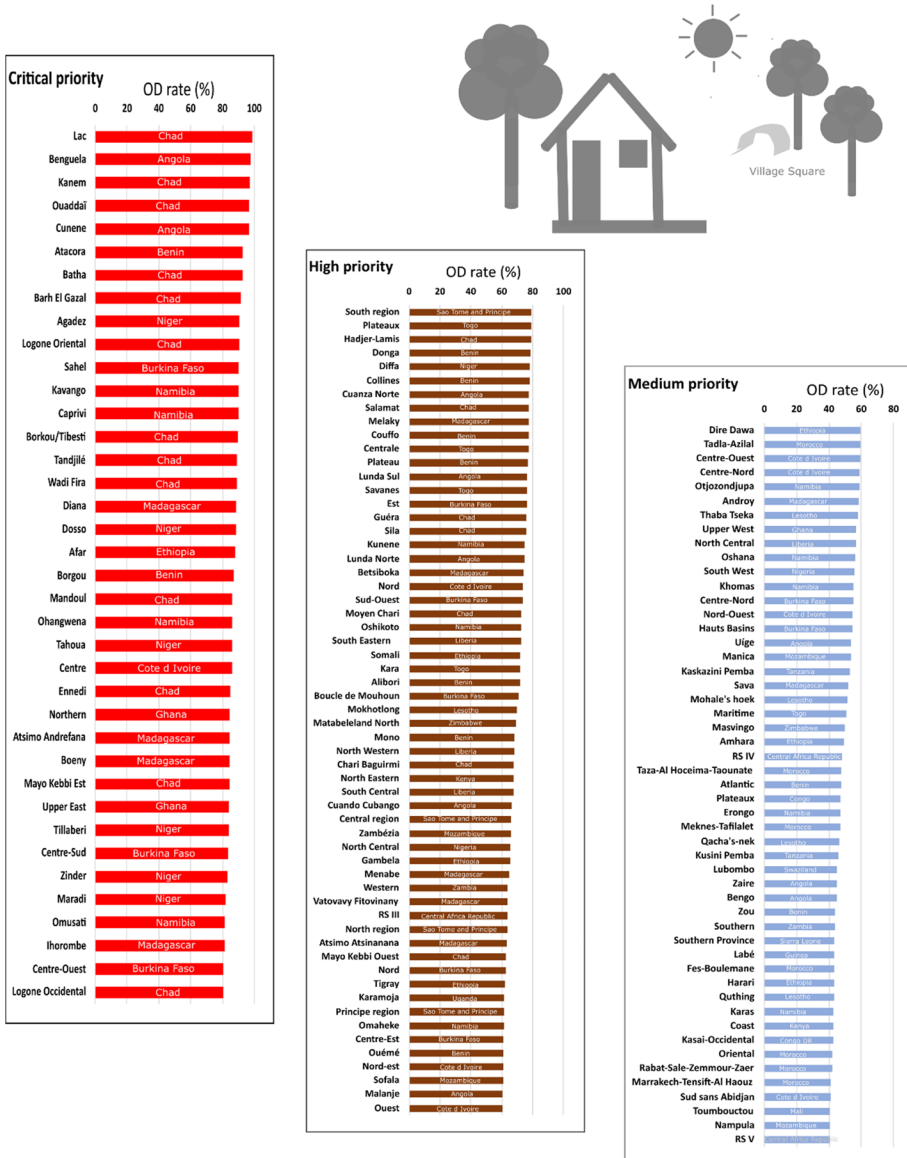


Fig. 2 Rural communities in Africa needing priority interventions against open defecation

open defecation priority systems. The datasets analysed were from the Demographic and Health Survey (DHS, 2022).

Table 6 shows that the availability of toilets is directly proportional to the wealth index. Within countries with critical sanitation challenges, the poor (i.e. the poorer and the poorest) account for about 60.8% of the total open defecation compared to 14.7% among the rich (i.e. the richer and the richest). Similarly, the higher the level

Table 5 Summary of countries that have regions with critical open defecation rates

Countries with geographical regions in critical state by number of regions

Countries	Total region	Urban			Rural		
		Critical	High	Medium	Critical	High	Medium
Angola	18	0	0	0	5	5	3
Benin	12	1	0	7	2	7	2
Burkina Faso	13	0	1	0	3	5	2
Chad	21	0	2	6	13	7	0
Cote d'Ivoire	11	0	0	0	1	3	4
Ethiopia	11	0	0	0	1	3	3
Ghana	10	0	0	1	2	0	1
Madagascar	22	0	0	3	4	5	2
Namibia	13	0	1	4	4	3	5
Niger	8	0	0	0	6	1	0
Sao T&P	4	1	0	3	0	4	0

Table 6 Descriptives and regression case processing summary

Wealth index						
Toilet type	Poorest	Poorer	Middle	Richer	Richest	Total
Flush	1166	5787	12,462	21,156	43,240	83,811
Latrine	16,751	36,148	47,838	55,788	73,088	229,613
No toilet	120,742	80,829	60,043	38,245	6879	306,738
Total	138,659	122,764	120,343	115,189	123,207	620,162
<i>Highest educational level</i>						
Toilet type	No education	Primary	Secondary	Higher	Don't know	Total
Flush	23,493	24,775	26,001	6537	360	81,166
Latrine	86,097	61,328	31,991	5461	361	185,238
No toilet	172,526	72,130	19,329	807	274	265,066
Total	282,116	158,233	77,321	12,805	995	531,470
<i>Type of place of residence</i>						
Toilet type	Urban	Rural	Total	Not applicable		
Flush	69,850	13,961	83,811			
Latrine	102,853	126,760	229,613			
No toilet	39,625	267,113	306,738			
Total	212,328	407,834	620,162			

of education, the lower the possibility of practicing open defecation. The datasets were from the Demographic and Health Survey (DHS, 2022). A flush toilet is common in urban areas, while open defecation is common in rural areas. However, the latrine is used in both urban and rural areas.

Logistics regression analyses of the eleven countries with critical priority regions are presented in Fig. 5. Figure 5a indicates that the poorest in these countries are more likely to be without a toilet and practice open defecation. After adjusting for covariates, the poorest are 43 times more likely to practice open defecation than the richest (95% CI=42.443–45.290). Even the wealthier people are about five times more likely to practice open defecation than the richest (95% CI=5.039–5.355).

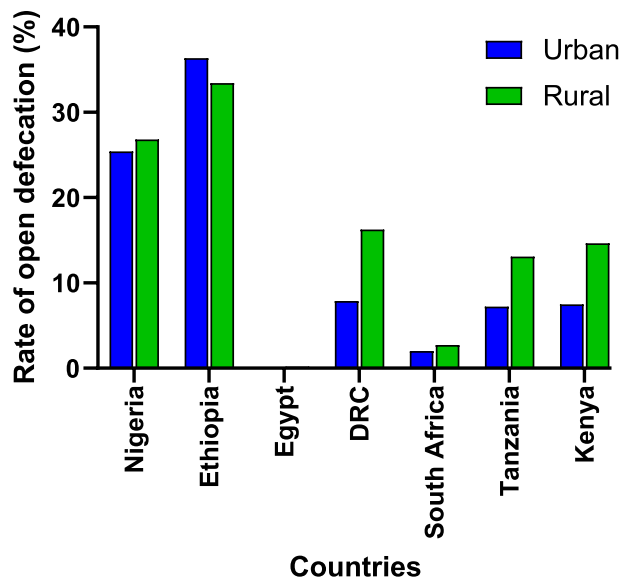
Open defecation rate in seven most populous countries in Africa, namely Nigeria, Ethiopia, Egypt, Democratic Republic of Congo (DRC), South Africa, Tanzania and Kenya, is presented in Figs. 3 and 4 using datasets analysed were from the Demographic and Health Survey and World Bank population ranking (DHS, 2022; World Bank, 2023).

The year of the survey dataset used for figures 3 and 4 are Nigeria (2018), Ethiopia (2016), Egypt (2014), DRC (2013), South Africa (2016), Tanzania (2016) and Kenya (2014).

The length of the boxes in Fig. 4 indicates the margin in rural vs urban areas. Among these seven populous Africa countries, open defecation rate is lowest in Egypt. Egypt peak OD practice is among the most impoverished rural residents, and the rate is about 0.6%. On the other hand, OD is highest in Ethiopia, especially among the poorest residents in rural (82%). Generally, the poorest in urban areas have a reduced open defecation rate than the poorest in rural areas. The margin among the poorest is vast in Kenya, Ethiopia, and Democratic Republic of Congo (DRC). Among the richest in DRC, the place of residence widens the open defecation rate.

For African regions with critical state, the poorest are 43 times more likely to defecate in the open than the richest (Fig. 5a). However, beyond the binary of “had toilet” and “no toilet”, multinomial categorisation (flush, latrine, and no toilet) revealed how vast toilet- ing inequalities could be (Figs. 5b and c). For instance, Fig. 5c indicates that among people with no toilet, the poorest are 117 times more likely to practice open defecation (95% CI=110.172–125.786) than the richest. The regression analyses indicate that in areas with critical OD practice, wealth index is a vital factor that promotes this sanitation indicator.

Fig. 3 Open defecation rate in seven most populous countries in Africa



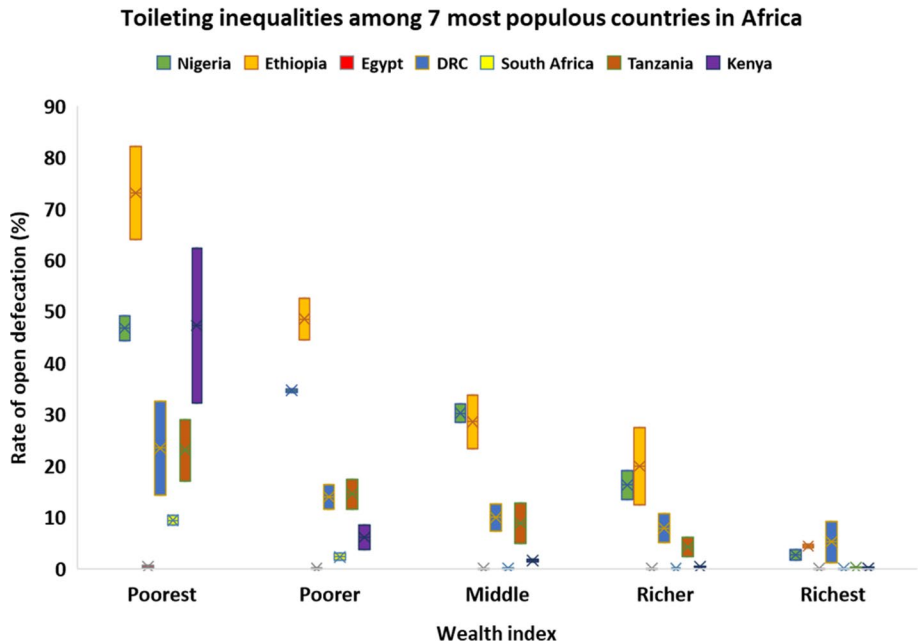


Fig. 4 Toileting inequalities among Africa's *big seven*

4 Discussion

Poverty or wealth index is a factor linked to the incessant practice of OD (Figs. 4 and 5). Nigeria's position is crucial in determining the success of open defecation-free (ODF) Africa because of its poverty rate of 43%, which is about 89.8 million people (WPC, 2021). Africa will require a concerted effort to be ODF since 263 million people across Nigeria, Ethiopia, Niger, DR Congo, Burkina Faso, Chad, Angola, Madagascar, Kenya, and Cote d'Ivoire live in extreme poverty (Table 2, WPC, 2021). These ten countries with toilet emergency account for about 54% of Africans in extreme poverty, and the current trend suggests that ODF status in these countries may not be achieved by 2030. Albeit this may be readily implemented through the combined efforts of the government and a broad range of stakeholders in building a solid foundation for access to sanitation (UNICEF and WHO, 2020). In 2008, the African Union (AU) acknowledged the crucial role of water and sanitation in promoting social, economic, and environmental development for member countries and the entire African continent (AU, 2008). Albeit, five years after, these WASH pledges were not reflected in the continent's big agenda. In January 2013, the AU summit adopted Agenda 2063—The Africa We Want. The 50-year-long agenda is intended to be Africa's blueprint and master plan for sustainable development and the continent's economic growth (AU, 2021; NEPAD, 2020). Commitment towards ending open defecation or safe and hygienic toilets for all is not made in the "The voices of the African people" 63 statements (AU, 2015). At first while AU attempted to link its agenda with the global sustainable plan, none of the goals and priority areas clearly addressed sanitation (AU, 2021). The first implementation report by the pan-Africa body does not contain sanitation (NEPAD, 2020). However, the 2022

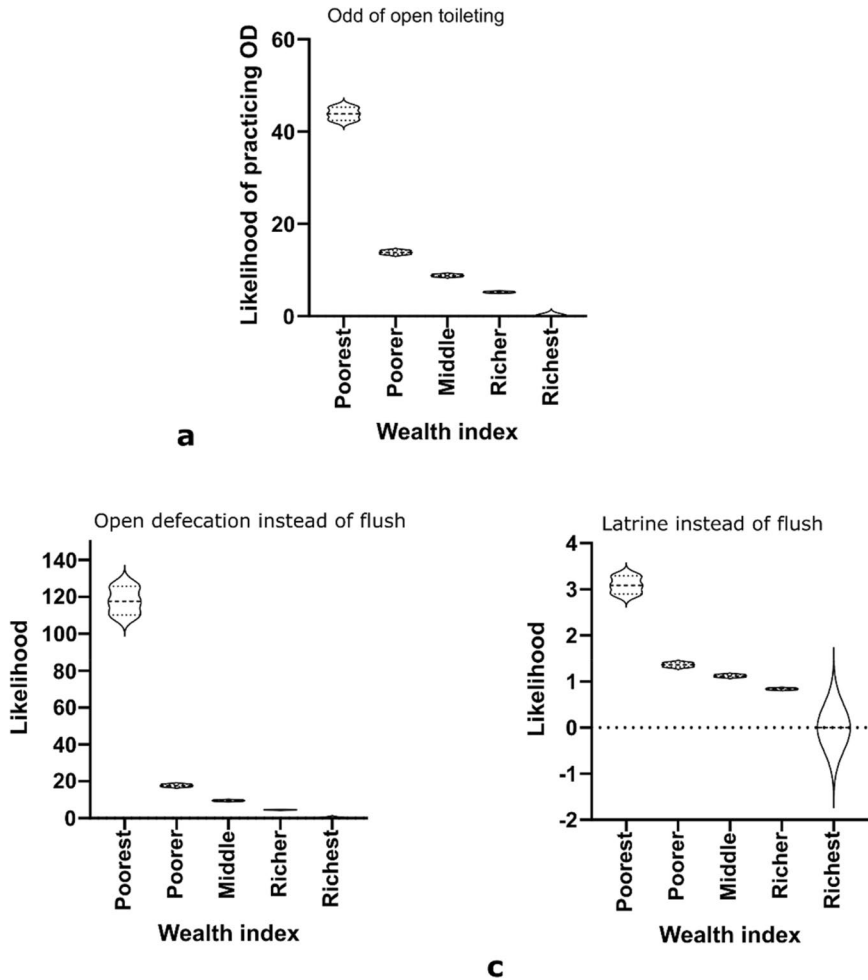


Fig. 5 Logistic regression of African regions in critical state. The likelihood of (a) practicing open defecation, b Open defecation instead of flush toilet, c using latrine instead of flush toilet

implementation report had sanitation as an indicator in one of the priority areas of goal one (NEPAD, 2022). Sadly, sanitation is an afterthought within the continent's own agenda. The present analysis (Table 2) and low progress and commitment to sanitation suggest that open defecation may continue in Africa until 2030 or beyond.

Notwithstanding, recent times have seen a renewed continental effort on sanitation. Firstly, in 2015, Ngor Declaration was made by African Ministers Council on Water (AMCOW), a specialised committee for water and sanitation in AU. The declaration calls for universal access to adequate and sustainable sanitation and hygiene services and for eliminating open defecation by 2030 (AMCOW, 2019). AMCOW seeks to respond to the need to reform sanitation policies in the continent to reduce the number of people without access to sanitation services and improve access to safely managed sanitation. A recent output of the declaration is the African Sanitation Policy Guidelines (ASPG), designed to guide African governments in reviewing, revising, and developing sanitation policy and its

implementation strategy (AMCOW, 2021). While this is a laudable effort, implementing the country-specific sanitation policy may present a bottleneck.

4.1 Wealth and health

The results in this study highlight that poverty line is still a determining factor why people defecate in the open, especially in areas where the OD rate is $\geq 80\%$ (Fig. 5). After adjusting for education and place of residence covariates, the poorest are 43 times more likely to practice open defecation than the richest (95% CI=42.443–45.290). Nigeria and Ethiopia are core drivers of the African population practicing open defecation (Figs. 3 and 4). Some years back toileting intervention in India failed partly because the poorest were provided with toilets without inspiring behavioural change about sanitation (Singh and WSP, 2007). There are similar reports of the negative influence of lower socioeconomic status on open defecation practice in Kenya (Busienei et al., 2019a, 2019b), India (Vyas et al., 2019), Nepal (Bhatt et al., 2019), and Ghana (Adzawla et al., 2020). Truly, behavioural change is essential as toilet provision does not always equate to the end of open defecation. Notwithstanding, positive wealth status can stimulate positive behavioural change about sanitation. Studies have shown that income is associated with better health, and wealth affects health (Braveman et al., 2010; NCHS, 2012; Pollack et al., 2013; Gordon et al., 2020). Perhaps, more Africentric or country-specific studies need to be carried out on socioeconomic status and health.

4.2 Toileting issues in West Africa and the high burden of antimicrobial resistance

Historically, open defecation has been endemic to West Africa, and the trend subsists in the region (Tables 1, 2, 3, 4). OD practice is prevalent in West African countries. For instance, Nigeria has the highest number of people in the continent practising OD (Table 2). Other Countries that share boundaries with her, viz. Niger, Chad, and Benin, also struggle to end open defecation (Table 4). Urban open defecation is at a critical-priority level in the *Atacora* region of Benin and the *Est* region of Burkina Faso (Fig. 1).

Furthermore, out of the 42 regions with a critical rural OD rate, 27 (64%) are West African sub-national (Fig. 2). *Atacora*, a largely rural area, is the poorest in Benin in non-monetary poverty (World Bank, 2009). *Atacora* lies in north-western Benin and shares a border with the *Est* region of Burkina Faso. Both regions share a forested, rugged mountainous range and a sanitation dilemma. Sanitation bottlenecks in these regions include harmful social norms and the unwillingness of households to build, use and manage the toilets. Because of the mountainous terrain, the regions also face hydrogeological challenges that impede borehole drilling and the use of flush toilets (UNICEF Burkina Faso, 2019). CLTS is being implemented by local enterprises that construct toilets, and villages get ODF status and certification. Sustainability checks in Côte d'Ivoire, Benin and Ghana reveal that there is a high rate of post-ODF slippage, and this is a result of a decline in the use of latrine toilets. The decrease in the use of toilets was reported to be due to the use of low-quality hardware for toilet construction, low know-how capabilities of the local monitoring committee, limited involvement of local authorities in programme implementation, and uncompetitive commercial sanitation market (Jiménez et al., 2017).

West African regional bloc, the Economic Community of West African States (ECOWAS), formed its health arm in 1987 to protect member states' health. However, since 2000, when West Africa Health Organisation (WAHO) became operational, there has been

no strong leadership in sanitation until recently with ECOWAS Vision 2050 (WAHO, 2020; ECOWAS, 2022). It is not enough to have a few mentions of words like 'sanitation' or 'WASH' in policies, rather, statements need to be backed with commitments, initiatives and influence on member states towards ODF. For instance, the press release by WAHO to mark 2020 *World Toilet Day* does not highlight the degree of the problems of open defecation in West Africa. By referring to only global statistics instead of succinct regional facts and implications, it appears WAHO does not grasp the magnitude of OD in its region. The open defecation challenge in ECOWAS is beyond the annual November 19th statement, press release and one-off ceremony. It is noteworthy that less than a decade to 2030, ECOWAS and its specialised health agency WAHO do not seem to have a solid road map on ODF or any WASH component.

The World Health Organisation has recognised antimicrobial resistance as a priority 'global health epidemic' and 'development threat' facing humanity (WHO, 2021). Of all the regions and sub-regions of the world, west Africa has the highest all-age death caused by drug resistance (Murray et al., 2022). Furthermore, it is confirmed that antibiotics residues are present in faecal wastes, which increases the burden of AMR which can be release to the environment, a predominant case in West Africa (Sclar, 2016; Paruch et al., 2019; Hendriksen et al., 2019; Wilkinson et al., 2022). Indeed, west Africa has a huge and significant toilet problem that could be driving the high burden of AMR in the region and worldwide (Murray et al., 2022).

4.3 Water sanitation and hygiene financing and the lesson from Egypt and South Africa

As shown in Table 3, Egypt has been leading Africa in successful access to sanitation, which WaterAid also reported (2015) and recent AU agenda 2063 (NEPAD, 2022). Unlike the OD rate of 0.7% presented in Table 3, WaterAid reported that Comoros has a challenge with access to sanitation (64% of the population). It is to be noted that the result used the year 2012 datasets, which are the latest publicly available datasets for Comoros. WaterAid may have used more recent data that are unavailable as at the time of data analyses in 2021. More so, it reported a percentage (%) of the population without access to sanitation, not specifically % of OD. A similar disparity is observed for Rwanda, Cameroon, and a few other countries with old data. Despite the successes of Egypt, with a low rate of open defecation, because most households have latrines or flush toilets, wastewater management is still a challenge (Harmsen et al., 2014). This challenge is common in rural Upper Egypt or Nile Delta because of the high population density (Harmsen et al., 2014; World Bank, 2015). The country has used a CLTS-type approach for sanitation and waste management (IIED, 2010). More importantly, the secret to eliminating open defecation is an investment in WASH. Between July 2014 till July 2020, Egypt invested EGP 174 billion to ensure equitable and sustainable water and sanitation (about USD 11 billion) (Mohammed, 2020). Likewise at the end of apartheid in South Africa, the government committed to financing the implementation of WASH policies (GoSA and UNDP, 2005). Consequently, open defecation dropped from 12.4% in 2000 to 1.4% in 2017 (WHO/UNICEF JMP, 2021). Table 3 presents 2.6% for South Africa, a slightly higher rate. Ensuring proper sanitation goes beyond the construction of toilets, as these structures will inevitably reach their capacity and potentially become inoperable. To overcome this and offer a long-term maintenance plan, there was an early commitment to WASH research and community engagement in the middle-income country of South Africa (Ntaro et al., 2022; Still et al., 2012; Jacobs

et al., 2014) Government-led funds in Africa will play a crucial role in promoting scientific knowledge and practical solutions for the efficient management of faecal wastes and eradicating open defecation.

5 Conclusions

Open defecation presents major health and socio-economic challenges in developing nations. To combat such challenges, the UN initiated the MDGs and later, the SDGs. However, nearing the SDGs 2030 deadline, Africa lags in several areas, especially in the adoption of safely managed toilets. This research delves into the practice, status, and causes of open defecation across Africa using the DHS Program datasets, spanning eight million participants from 39 countries. Results show a longstanding issue of open defecation in Africa. Disturbingly, ten of these countries are predicted to have about 247 million inhabitants lacking safe toilets by 2030. This underscores the dire need for enhanced leadership and action by African organizations and nations to enforce, track, and assess sanitation initiatives. A key finding is that poverty greatly influences open defecation, with impoverished individuals being significantly more likely to engage in the practice. Rural areas face larger disparities in toilet access, intensifying the issue. Thus, empowering these communities and offering community-based sanitation services is vital for an open defecation-free Africa. The interconnectedness of SDGs, especially between SDGs 6, 1, 3, 4, and 11, emphasizes the importance of sanitation in promoting health, sustainability, and education. Furthermore, given the high burden of AMR in Africa and increasing reports of drug-resistant pathogens in faeces, there is an urgent need to address AMR by curtailing open defecation. Interventions and assessments should be viewed through the lens of One Health. This implies adopting holistic multisectoral strategies to amplify surveillance and stewardship initiatives in the priority areas, communities, and nations identified in this study. Policymakers should focus on data-driven strategies to eliminate open defecation, especially in the hardest-hit areas. The study's limitation lies in its reliance on DHS datasets, which may have biases and miss out on the most recent trends. Despite these shortcomings, the research offers invaluable insights into the open defecation crisis in Africa, emphasizing the need for immediate, data-informed, and multidisciplinary interventions.

5.1 Recommendations

Based on the findings of this research, some policy recommendations for addressing the issue of open defecation in Africa should include first, targeted and data-driven interventions to facilitate needs-based approach that focus on regions and communities in urgent need. The findings of the study highlight the critical, high, and medium priority areas, which can guide the allocation of resources and intervention strategies.

Secondly, there should be emphasis on community-led total sanitation. The CLTS has been relatively successful in reducing open defecation in many parts of the world. The use of appropriate policy has the potential to lead to a high uptake of the model in several African countries to help combat open defecation in their communities.

Thirdly, it is important to address poverty and inequality to improve sanitation. Inequalities in toileting were observed among individuals living in poverty or in rural areas. Lack or inadequate sanitation infrastructure is a significant contributor to open defecation in Africa. Governments should invest in the improvement of sanitation infrastructure,

including the construction of public toilets and sanitation facilities in rural areas backed with community support and leadership. Governments and regional bodies through dedicated agencies should create a special fund or allocate a percentage of the government budget towards sanitation infrastructure. Interventions should target the root causes of poverty and inequality, which drive open defecation.

Fourthly, it is essential to understand and promote positive behavioural change on sanitation. Insights from behavioural studies can be used in diagnosis and development interventions that are essential for combating open defecation. Governments across Africa should promote behavioural change through awareness campaigns, education, and social marketing to encourage people to use toilets and improve hygiene practices.

Fifthly, important surveys such as demographic and health survey which are widely deployed in developing countries should incorporate variables that will assist in surveillance of antimicrobial resistance, including the collection and genomic analyses of environmental samples or faecal samples from selected sites and household during the survey.

Finally, collaborations and partnerships with governments, non-governmental organisations, funding bodies and other stakeholders are crucial to share knowledge, resources, and expertise to end open defecation in Africa. The involvement of the private sector and alternative funding mechanism is vitally important in promoting sanitation infrastructure development and investment in sanitation programs.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s10668-023-03992-6>.

Data availability The data used in this study are publicly available and accessed at <https://dhsprogram.com/>, explored by country, survey type and year.

Declarations

Conflict of interest The authors did not receive support from any organization for the submitted work. The authors have no relevant financial or non-financial interests to disclose.

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