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REVIEW **Open Access**

Mapping and gap analysis on antimicrobial resistance surveillance systems in Kenya, Tanzania, Uganda and Zambia

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Abstract

Background Antimicrobial resistance is a global problem and involve pathogens which have the potential to move between food producing animals and humans by direct exposure or through the food chain or the environment. The objective of this study was to determine the performance in addressing antimicrobial resistance in Kenya, Tanzania, Uganda and Zambia. Desk review and in-depth interviews were employed for data collection. Interviews were conducted with national antimicrobial resistance focal officials.

Results The findings indicate that in the four countries there was minimal capacity to conduct AMR surveillance. There were few well-established laboratories in tertiary hospitals, both private and public hospitals. The animal, environment and agricultural sectors in all countries had limited capacity in conducting antimicrobial resistance surveillance. There is limited data on antimicrobial resistance in all the four countries, and regional data sharing was limited. In all the four countries, data from research institutions were not linked using standardized system making difficult to compile the national database. The capacity for microbiological culture, identification and antimicrobial sensitivity testing using standardized protocols was available in the four countries. The interventions adopted by the countries included development of National Action Plans on antimicrobial resistance and setting up of multi-sectoral national coordinating structures.

Conclusions Based on this findings, the countries need improved National Integrated Antimicrobial Resistance Surveillance systems to include community settings, involving antimicrobial use and resistance in human, animal, food, and environment sectors. In addition, the region requires clear antimicrobial resistance data sharing protocol for quick comparability of the data across the region. This is important in driving antimicrobial resistance agendas at regional level, which will eventually trigger collective actions.

Keywords Antimicrobial resistance, Surveillance data, Capacities, Kenya, Tanzania, Uganda, Zambia

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Background

Antimicrobial resistance (AMR) is a growing global public health and economic challenge and is recognized as a silent pandemic that threatens to kill up to 10 million people by 2050 (de Kraker et al. 2016). The problem is of great concern, particularly in low- and middle-income countries (LMICs), including Sub-Saharan Africa, where antimicrobials are widely available and inappropriately overused in human and animal health (Tadesse et al. 2017; Elton et al. 2020; Mshana et al. 2021), and there is lack of alternatives to ineffective antimicrobials (Kariuki et al 2022). In Africa, the all-age death rate attributable to AMR is the highest (at 27·3 deaths per 100,000) (AMR Collaborators 2022). Although AMR is a global issue, in Africa the problem is made worse by weak regulations in crops, human and animal health practices, weak surveillance systems for AMR and antimicrobial use (AMU), and lack of updated standard treatment guidelines for human and animal diseases (Mshana et al. 2021). Even where there has been appropriate regulation for antimicrobial stewardship compliance can be variable (Engker et al. 2021). Other factors include lack of access to appropriate antimicrobial therapy, lack of continuing medical/veterinary education on AMU for prescribers (Frumence et al. 2021); tendency for animal owners to stock drugs in their houses and engaging unskilled people in treating animals (Frumence et al. 2021); and failure in observing the recommended therapeutic doses, use of wrong routes of administration, arbitrary drug combinations and non-observance of withdraw periods among livestock farmers (Afakye et al. 2020).

LMICs have weak health systems, with limited laboratory capacity to collect and analyse data on AMR and AMU. The human and livestock health systems significantly lack both human resource and infrastructures to address the AMR and AMU problem in the context of One Health (Mshana et al. 2021). In addition, there are challenges that are contributed to low number of clinicians and presence of substandard antimicrobials and diagnostics in these countries. The nations and regions need to invest now when many LMICs are in the early stages of strengthening basic capacity in livestock sector and human sector for AMR and AMU surveillance to ensure more on the coordination among sectors and among countries and regions so that data that will be obtained are comparable (Fuhrmeister and Jones 2019).

Notably, an effective AMR and AMU surveillance system needs to consider integration, prioritization, comparability, investment and availability (Frost et al. 2021). The system should consider integration of existing systems and local to global One Health. Due to geographical and economic differences among countries and region prioritization and establishing region protocols that will bring impact is mandatory. AMR is a global problem and involves multiple sectors, and pathogens do not have geographical and ecological boundaries (Siahaan et al. 2022). In addition, the use of antimicrobials in humans, animals, plants and environmental contamination of these antimicrobials can lead to resistance development in any of the sector. The systematic collection of AMR and AMU data locally, nationally and regionally can allow wide spectrum of quality data to be comparable and shared in global systems. Therefore, there is a need of establishing common protocols to cater for various sectors and address local, national and regional AMR priorities (Mshana et al. 2021). The developed protocols should ensure integration, prioritization based on the national and regional needs, comparability of local and national data, and sustainability of the investment and availability of a system to share data and visualization of the data for reporting and further analysis, especially by policy makers.

Hence, there is a need of standardization and harmonization of Antimicrobial Susceptibility Testing (AST) guidelines to produce national guidelines (van Beikum et al. 2019). Furthermore, major modifications in the AST, bacterial isolation and identification protocols used are required to improve their adaptation to national AMR surveillance objectives. This is important to ensure relevance of diagnostic techniques that are used by laboratories are included in the AMR surveillance system. This study aimed to map the existing AMR systems, identify the gap and prioritize the need to ensure impact in both human and animal health.

Methods

Literature reviewed to extract information on the status of antimicrobial use, antimicrobial resistance and availability of surveillance systems and protocols in the four countries

Desk review was carried out between December 2019 and March 2020. Pub-Med, Google Scholar, Web of Science, Africa Wide Information and African Journal Online databases were searched for information on AMU and AMR from Kenya, Tanzania, Uganda and Zambia. Research articles and review papers written in English were considered. In addition, publications from Food and Agriculture Organization (FAO), World Health Organization (WHO), International Livestock Research Institute (ILRI), Office International des Epizooties (OIE) websites were also searched and reviewed. Combinations of search terms used were 'antimicrobial use', 'antibiotic use', 'antimicrobial resistance', 'antimicrobial resistant'; others were specific such as 'humans', 'children', 'MRSA', 'ESBL', '*Escherichia coli*', '*Staphylococcus aureus*', "*Klebsiella pneumoniae*", 'poultry', 'chickens', 'pigs', 'swine', 'cattle', 'beef cattle'. In addition, we used other key word such as surveillance, action plan, national plan, protocol, guidelines, and report. The articles were scrutinized to extract information on the antimicrobial use, prevalence of AMR and availability of a surveillance systems and protocols.

In-depth interviews with antimicrobial resistance (AMR) focal persons in the four countries

In each country, contacts for AMR focal persons were engaged. The objectives of the study were explained and each participant was requested to fill a questionnaire. Then a zoom meeting was scheduled for each at their own convenience with a request that it should happen when the questionnaire is already filled. The zoom meeting interview was conducted between the investigators and each of the AMR focal points in separate meetings. Inquiries made during the interviews specifically aimed at complementing the PARSE tool responses.

The primary data collection was done in Kenya, Tanzania, Uganda and Zambia between February and May 2020. Data was manually extracted from the collection tool and summarized. The guide questions were further developed to collect more data or clarify what was written from contact focal persons of each country. Other data sources included: National AMR documents such as National Action Plan (NAP) on AMR and Antimicrobial Resistance Surveillance frameworks.

Primary data sources used in evaluating the status of antimicrobial surveillance systems in the four countries

The primary data collection was done in Kenya, Tanzania, Uganda and Zambia using the Partnership on Antimicrobial Resistance Surveillance Excellent (PARSE) tool between February and May 2020. Data were manually extracted from the tool and summarized. The guide questions were further developed to collect more data or clarify what was documented during the in-depth interviews. Other data sources included Multi-sectoral National Action Plan (NAP) and Antimicrobial Resistance Surveillance frameworks and the respective Joint External Evaluation EE reports.

Results

Number of participants who were consulted by country and position

A total of 27 individuals were consulted (Kenya = 6; Tanzania = 7; Zambia = 11; Uganda = 3) (Table 1).

Table 1 Key stakeholders consulted by country and position

Country	Position
Kenya	National AMR Focal Point
	Animal Health—Terrestrial and Aquatic Focal Point
	Food Safety Focal Point
	Animal Health Surveillance Focal Point
	World Health Organization AMR Focal Point
	Food and Agriculture Organization AMR Focal
Tanzania	National AMR Focal Point
	Chairman, National Surveillance Technical Working Group
	Animal Health AMR Focal Point
	Plant Health AMR Focal Point
	Director, National Reference Laboratory
	Chairperson, AMR Animal Health Technical Working Group
	Chairperson, AMR Human Health Technical Working Group
Zambia	National AMR Focal Point
	Human Health Surveillance/ Epidemiology (2)
	Human health decision-maker
	Plant Health
	Food safety
	Animal Health—Terrestrial And Aquatic
	Environment
	WHO AMR Focal Point AMR Surveillance
	FAO AMR Focal Point Surveillance
	OIE AMR Focal Point Surveillance
	Other Sector
Uganda	National AMR Focal Point
	Human Health Surveillance/Epidemiology
	Uganda National Antimicrobial Resistance Sub-committee

Prevailing national policies and guidelines on antimicrobial use and antimicrobial resistance

The surveillance framework in Zambia has identified three thematic areas: (i) Surveillance of antibiotic resistance in human health sector, (ii) surveillance of antibiotic resistance and antibiotic residues in food-animal sector and (iii) Surveillance of antibiotic resistance and antibiotic residues in the environment. In Tanzania, the AMR surveillance framework covers both human and animal sector. There are currently no integrated surveillance frameworks in Uganda and Kenya. Both Kenya, Tanzania, Uganda and Zambia have adopted the Global AMR action plan to draft their national action plans on AMR.

The National AMR Action plans in Kenya, Tanzania, Uganda and Zambia were contributed by both local and international stakeholders with involvement of high level leadership from the Government. This shows huge investment and political will of these countries to address the AMR problem. Data sources for AMR and AMU surveillance in the four countries include: Humans, Animals/Fisheries, Environment, Food and Plant sectors; Public health facilities; Animal health facilities; Research institutions; Veterinary and Medical laboratories and Health and Farmer professional associations. None of the protocols for AMR surveillance were available in the four countries.

Kenya's Ministry of Health launched its National Antimicrobial Steering Inter-Agency Committee in 2019, which is aligned with the country's AMR policy. Promoting sound antimicrobial stewardship (AMS) at the point of care helps to keep antimicrobials effective by decreasing inappropriate use. In addition, the country has launched the National Medicines and Therapeutics Committee, which revised Kenya's essential medicines list and incorporated.

Capacity of existing regional antimicrobial resistance surveillance systems

In each country, there is minimal capacity to conduct AMR surveillance. There are few well-established laboratories in tertiary hospitals, both private and public hospitals. The animal, environment and agricultural sectors in all countries have no capacity in conducting AMR surveillance. In Tanzania, there is a policy for ensuring quality of laboratory diagnostic capacities. The national laboratory quality standards/guidelines have been established. There are different levels of laboratories with different capacities. Laboratories at referral and zonal levels participate in international externa quality assurance (EQA) schemes. Staff at all Regional, Zonal and Reference Laboratories have been trained in laboratory practices for isolation, identification and antimicrobial susceptibility testing (AST) of different pathogens. In the human health sector, there are 32 laboratories in Tanzania with the capacity of performing culture and sensitivity with limitations. Of the 32 laboratories, 11 have been accredited by Southern African Development Community Accreditation Services under ISO 15189:2012.

In Uganda, laboratories that are conducting routine microbiological cultures are few. In 2014, only two of the seven regional referral hospitals had comprehensive capacity to conduct microbiological culture. A laboratory network that integrates identification, surveillance of enteric pathogens and their antibiotic resistance patterns of major classes of pathogens responsible for enteric infections has been established. Uganda has a well-functioning One Health AMR/AMU surveillance governance structure that provides technical support for the AMR and AMU. On the other hand, In Zambia, there is a formal multi-sectoral governance or coordination mechanism on AMR. These sectors include human health, animal health (terrestrial and aquatic), plant health, food production, food safety and environment. The country has limited capacities for quality assurance including clinical quality assurance and site laboratory quality assurance.

Status of regional data management and sharing mechanisms

There is no regional data sharing system in the region. However, in Kenya, Tanzania and Uganda, there is a project (*Holistic Approach to Unravel Antibacterial Resistance in East Africa)* in which sharing of data on the AST data for urinary tract infection pathogens is being done. The HATUA data are generated to assist in understanding the drivers of AMR in East Africa. Though AMR surveillance frameworks have clearly indicated how data will be shared among sectors in each specific country, there is no sharing of data among sector between countries. There are no regional protocols for response when AMR is detected. This has not been covered within the countries. In both four countries, Data from research institutions are not linked using standardized system making difficult to compile the national database. In some hospitals, especially national/tertiary/ university teaching hospitals the AMR data are collected in the computer-based system.

Capacity of microbiology laboratory services

In all countries, the tertiary/national hospitals and university teaching hospitals have capacity for culture, identification and sensitivity testing using standardized protocols. In each country, there is a National reference laboratory for human health and animal health. These laboratories have been overseeing the issue of quality testing.

Existing policies and guidelines regulating the use of antimicrobials in both in human and animal

Countries have a number of policies and guidelines regulating the use of antimicrobials in both in human and animal. Kenya has developed the Legal Notices No. 25 of 2010 that prohibited use of chloramphenicol and nitrofurans in food producing animals and various. Others, include: (i) Pharmacy and Poisons Act; (ii) Food, Drugs and Chemical Substances Act; (iii) Medical Practitioners and Dentists Act; (iii) Animal Diseases Act; (iv) Public Health Act; (v) Pest Control Products Board (Act and (vi) Veterinary Surgeons and Veterinary Paraprofessionals Act.

Tanzania has the Drug Policy of 1993, which is the national policy on medicine us. There are National Essential Medicine List and Standard Treatment Guidelines which guide the rational use of medicines including antibiotics. In the animal health, there are several policies including: (i) National Livestock Policy of 2006; (ii) the Veterinary Act of 2003; (iii) Fisheries Policy of 1997; and (iv) and Fisheries Act of 2003. However, none of the policies for human or animal health directly addresses the issue of antibiotic resistance. Uganda has developed national policy guidelines for bio-banking. It provides guidelines that cover the acquisition, storage, sharing and use of biological materials in research and healthcare and associated data in health, agriculture; horticulture, animal, forensic, environment, aquatic sciences, wildlife and education and the National animal feeds policy. Zambia has developed the Zambian Essential Medicines List, 2013 and standard treatment guidelines to ensure appropriate prescriptions of medicine including antibiotics.

Existing drivers of antimicrobial resistance

As regards to AMR drivers, there is no extensive data in the region to clearly pin point the main drivers of the AMR. However, based on the research articles, a number of drivers have been documented. These include: (i) poor infection prevention and control in health facilities; (ii) overuse of antibiotics in medical, veterinary and aquaculture fields; (iii) lack of updated evidence-based antibiotic use and treatment guidelines; (iv) lack of surveillance of antibiotic use and resistance to provide data for appropriate empirical treatment guidelines; and (v) poor enforcement of laws and regulations in relation to AMR in animal, human and agriculture (Schar et al. 2018).

Multi-drug resistant pathogens identified in Kenya, Tanzania, Uganda and Zambia

Data from research have indicated AMR in a number of pathogens, including the World Health Organization high priority pathogens. These include *Acinetobacter* spp., *Pseudomonas* spp., ESBL producing Enterobacterales, *Enterococcus* spp., *Staphylococcus aureus*, *Neisseria gonorrhoeae,* responsible in causing varieties of the diseases (Table 2). The most prevalent are carbapenem-resistant *Pseudomonas* spp., *Acinetobacter* spp., *Klebsiella pneumoniae*, ESBL producing, vancomycin resistant *Enterococcus spp*. Antimicrobial resistance has also been reported in Methicillin-resistant *Staphylococcus aur*eus, Cephalosporin-resistant, fluoroquinolone-resistant Enterobacterales.

Existing interventional measures in the four countries

In all four countries, a number of interventions have been implemented. These include: (i) Setting up of multi-sectoral national structure to coordinate implementation of the country national AMR action plan; (ii) Development of country AMR national action, addressing the four objectives in the WHO AMR Global action Plan; (iii) Development of surveillance AMR Integrated surveillance protocols, with some countries including antimicrobial residues monitoring in different sectors; (iv) Strengthening the laboratories in both human and animal health; (v) Conducting training on identification, sampling, isolation, testing bacteria/pathogens to ensure quality AMR and AMU data are collected; and (vi) Data system development to ensure sharing of data among sectors.

Discussion

The four countries did not have AMR surveillance data, but all countries were in different stages of setting the systems. A recent review has shown that there is low AMR preparedness score compared to overall joint external evaluation (JEE score) (WHO 2017). This suggest that AMR has not been a priority for most Sub-Saharan African (SSA) countries, with the mean AMR preparedness score being 53% less than the overall mean JEE score (Elton et al. 2020). Factors that support and drive success in AMR capacity have been identified to include political commitment and collaboration among and between government and international stakeholders to utilize local and international expertise in supporting AMR surveillance development, as well as national policies on AMR surveillance developed within legal and ethical frameworks (Seale et al. 2017). AMR surveillance that links both data from health facilities, sentinel sites, national laboratories is important in identifying emergence of AMR and monitoring the trend in the country (Fuhrmeister and Jones 2019).

In this study, the four countries had limited information of the main AMR drivers. Imprudent and overuse of antimicrobials in medical, veterinary and agriculture have been associated with emergence and increase in AMR (Mshana et al. 2021). In addition, lack of access to quality healthcare has been identified as among the important drivers. Evidence indicates that the misuse of antimicrobials generates selective pressure in clinical environment (Holmes et al. 2016). Studies in these countries have identified AMR drivers to include the misuse and overuse of antimicrobials, self-medication, lack of access to clean water, sanitation and hygiene, poor infection and disease prevention and control in healthcare facilities. Others include weak enforcement of regulations, poor access to quality, affordable medicines, vaccines and diagnostics as well as lack of awareness and knowledge. Industrial and household improper disposal from healthcare facilities are known to provide selective pressures that enhance antimicrobial resistance (Peng et al. 2014; Hrenovic et al. 2017).

The findings indicate that in the four countries, there is minimal capacity to conduct AMR surveillance. Moreover, there was limited data on AMR in all the four countries. Regional AMR data sharing was informal and limited; yet in both four countries, data from research institutions were not linked using standardized system making difficult to compile the national

Table 2 Resistance phenotypes of multi-drug resistant pathogens identified in Kenya, Tanzania, Uganda and Zambia

Disease	Organism	Resistance phenotypes	
Human			
Sepsis	*Streptococcus pneumoniae*	MDR	Tadesse et al. (2017)
			Moore et al. (2019)
			Obakiro et al. (2021)
	S. aureus	MRSA	Tadesse et al. (2017)
			Manyahi et al. (2022)
	Klebsiella spp.	3GC, MDR	Tadesse et al. (2017)
	Escherichia coli	3GC, MDR	Obakiro et al. (2021)
	Enterobacterales	MDR	Tompkins et al. (2021)
Hospital acquired infections	*Klebsiella pneumoniae*	3GC, MDR	Fraser et al. (2020)
	Acinetobacter baumannii	3GC, MDR	Ayobami et al. (2019)
	Enterococcus cloacae, *Klebsiella pneumoniae* *E.coli*	MDR	Mutua et al. (2022) Manyahi et al. (2020)
	Pseudomonas aeruginosa	3GC, MDR	
	Enterobacterales	ESBL producing	Fraser et al. (2020)
	Staphylococcus aureus	Methicillin-resistant	Manyahi et al. (2022)
	Clostridium difficile	MDR	Mutai et al. (2021)
Meningitis	*Haemophilus influenzae*	AMP	
Urinary tract infections	*E. coli*	3GC, MDR	Kiiru et al. (2022)
	Klebsiella pneumoniae	3GC, MDR	Kiiru et al. (2022)
	Pseudomonas aeruginosa	3GC, MDR	Fraser et al. (2022)
Blood stream infections	*Enterobacteriaceae* *Pseudomonas aeruginosa*	MDR	Lord et al. (2021)
Diarrhoea	*Campylobacter jejuni* and *Shigella* spp	MDR	Zachariah et al. (2021)
Pigs	*Escherichia coli*	ESBL and quinolone resistant	Kabali et al. (2021)
Cattle	Campylobacter	MDR	Kashoma et al. (2015)
	Escherichia coli		Mainda et al. (2015)
Goat	*Escherichia coli*	MDR	Mwanyika et al., (2016)
Poultry	*Escherichia coli*	MDR	Shawa et al. (2022)
	Campylobacter	MDR	Chege (2022)
Fish	*Escherichia coli*	ESBL	Baniga et al. (2020)
Rodents, wild birds, flies	*Escherichia coli*	MDR	Hickman et al. (2022)
Environment	*Enterobacteriaceae*	MDR	Omulo et al. (2021)

3GC Third-generation cephalosporin, *MDR* Multi-drug Resistant, *MRSA* Methicillin-Resistant *S. aureus*

database. Countries with health systems are least able to respond to the emergence of AMR and the increase in the burden of infectious disease. Surveillance capacity depends on the existing health system and considerable investment is needed to develop laboratory infrastructure aligned to this. High-level expertise in-country to provide advocacy, championing and trusted guidance to the Ministry of Health is important. Studies in sub-Saharan Africa have identified weakness in data management and use for surveillance purposes. Most often, surveillance data are collected for reporting and not used for monitoring (Muhindo et al. 2016; George et al. 2020).

The capacity for culture, identification and sensitive testing using standardized protocols were available in the four countries. Antimicrobial susceptibility test to identify the regimen that is effective for an individual patient is important to avoid misuse of antibiotics. Moreover, it helps in evaluating treatment services provided by healthcare facilities and disease control programmes.

The countries have a number of policies and guidelines regulating the use of antimicrobials in both the human and animal health sector. The interventions adopted by the countries include setting up of multi-sectoral national structure to coordinate implementation of the country national AMR action plan and the development of country AMR national action plans. However, there were no evidence on the implementation of the policies or enforcement of the regulations. It should be noted that reducing AMR and assuring appropriate dispensing and use of medicine requires monitoring and enforcement of regulations. Enforcement of regulations is key in addressing the misuse, abuse, overuse of antimicrobials in both the human and animal health sectors (Holmes et al. 2016). It is an important components in enhancing the sustainability of policy objective. The UN Food and Agriculture Organization has outlined areas that enforcement is likely to have impact. These include: limiting non-therapeutic uses of antimicrobials; preventing the introduction of counterfeit medicine; controlling waste potentially contaminated with antimicrobials; controlling residues of antimicrobials in food, feeds, water and soil; and ensuring antimicrobials are labelled with necessary instructions and warnings (https:www.fao.org/antimicrobials-resistance/keysectors/legislation).

Conclusions

The findings indicate that in these four countries, there has been a significant increase in resistance to the commonly used antibiotics such as ampicillin, tetracycline, gentamicin, ciprofloxacin, cephalosporins among WHO priority pathogens *Acinetobacter* spp., *Pseudomonas* spp., ESBL producing Enterobacterales, *Staphylococcus aureus* circulating in human, animal and environment sector in these countries. These countries have adopted a One Health approach and have developed multi-sectoral National Action Plans on AMR and integrated AMR surveillance frameworks to combat and stop the spread of AMR. The countries need improved National Integrated Antimicrobial Resistance Surveillance systems to include community setting, healthcare-associated infections and antimicrobial use in human, animal, food, and environment sectors. There is a need for implementation of the Tricycle ESBL-Ec protocol using One Health approach and updated laboratory protocols on AMR methods. In The countries require clear AMR data sharing protocol for comparability of the data across the region. This is important in driving AMR agendas at regional level, which will eventually trigger collective actions.

Abbreviations

AMR	Antimicrobial resistant
AMS	Antimicrobial stewardship
AMU	Antimicrobial use
AST	Antimicrobial susceptibility testing
ESBL	Extended spectrum beta lactamase
FAO	Food and Agriculture Organization
JEE	Joint External Evaluation
ILRI	International Livestock Research Institute
MDR	Multi-drug resistant
MRSA	Methicillin-resistant *Staphylococcus aureus*
NAP	National action plan
OIE	Office International des Epizooties
WHO	World Health Organization

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Author contributions

MIM, SEM, MM, NM, EK and MMM conceptualized and designed the study. MIM, SE, NM, MM and EK involved in data collection and analysis. LM and MIM drafted the manuscript. All authors read and agreed to the submitted version of the manuscript.

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Availability of data and materials

All data generated during this study are included in this published article.

Declarations

Ethics approval and Consent to participate

The National Institute for Medical Research (NIMR) cleared this study with a certificate numbered NIMR/HQ/R.8a/ Vol.IX/3580.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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References

Afakye K, Kiambi S, Koka E, Kabali E, Dorado-Garcia A, Amoah A, Kimani T, Adjei B, Caudell MA (2020) The impacts of animal health service providers on antimicrobial use attitudes and practices: an examination of poultry layer farmers in Ghana and Kenya. Antibiotics 9(9):554. https://doi.org/10.3390/antibiotics9090554

Ayobami O, Willrich N, Harder T, Okeke IN, Eckmanns T, Markwart R (2019) The incidence and prevalence of hospital-acquired (carbapenem-resistant) *Acinetobacter baumannii* in Europe, Eastern Mediterranean and Africa: a systematic review and meta-analysis. Emerg Microbes Infect 8(1):1747–1759. https://doi.org/10.1080/22221751.2019.1698273

Baniga Z, Hounmanou YMG, Kudirkiene E, Kusiluka LJM, Mdegela RH, Dalsgaard A (2020) Genome-based analysis of extended-spectrum β-lactamase-producing *Escherichia coli* in the aquatic environment and Nile Perch (*Lates niloticus*) of Lake Victoria, Tanzania. Front Microbiol 11:108. https://doi.org/10.3389/fmicb.2020.00108

Chege EP (2022) Antimicrobial resistance patterns of *Campylobacter* species isolated from poultry in Mathira, Nyeri County, Kenya. JAC-Antimicrob Resist 4(2):dlac053.018. https://doi.org/10.1093/jacamr/dlac053.018

de Kraker ME, Stewardson AJ, Harbarth S (2016) Will 10 million people die a year due to antimicrobial resistance by 2050? PLoS Med 13(11):e1002184

Elton L, Thomason MJ, Tembo J, Velavan TP, Pallrla SG, Arunda LB et al (2020) Antimicrobial resistance preparedness in sub-Saharan African countries. Antimicrob Resist Infect Control 9:145. https://doi.org/10.1186/s13756-020-00800-y

Fraser J, Mwatondo A, Alimi YH, Varma JK (2020). Healthcare-associated outbreaks of bacterial infections in Africa, 2009–2018: a review. https://doi.org/10.1016/j.ijid.2020.12.030

Frost I, Kapoor G, Craig J, Liu D, Ramanan Laxminarayan R (2021) Status, challenges and gaps in antimicrobial resistance surveillance around the world. J Glob Antimicrob Resist. https://doi.org/10.1016/j.jgar.2021.03.016
Fuhrmeister AS, Jones RN (2019) The Importance of antimicrobial resistance monitoring worldwide and the origins of SENTRY antimicrobial surveillance program. Open Forum Infect Dis 6(Suppl 1):S1–S4. https://doi.org/10.1093/ofid/ofy346
George J, Häsler B, Mremi I, Sindato C, Mboera L, Rweyemamu M, Mlangwa J (2020) A systematic review on integration mechanisms in human and animal health surveillance systems with a view to addressing global health security threats. One Health Outlook 2:11. https://doi.org/10.1186/s42522-020-00017-4
Hickman RA, Agarwal V, Sjöström K, Emanuelson U, Fall N, Sternberg-Lewerin S, Jarhult JD (2022) Dissemination of resistant *Escherichia coli* among wild birds, rodents, flies, and calves on dairy farms. Front Microbiol. https://doi.org/10.3389/fmicb.2022.838339
Holmes AH, Moore LSP, Sundsfjord A, Steinbakk M, Regmi S, Karkey A et al (2016) Understanding the mechanisms and drivers of antimicrobial resistance. Lancet 387:176–187. https://doi.org/10.1016/S0140-6736(15)00473-0
Hrenovic J, Durn G, Music MM, Dekc S, Troskot-Corbic T, Skoric D (2017) Extensively and multi drug resistance *Acinebacter baumanniil* recovered from technosol at a dump site in Croatia. Sci Total Environ 607:1049–1055. https://doi.org/10.1016/j.scitotenv.2017.07.108
Kabali E, Pandey GS, Munyeme M, Kapila P, Mukubesa AN, Ndebe J, Muma JB, Mubita C, Muleya W, Muonga EM, Mitoma S, Hang'ombe BM, Wiratsudakul A, Ngan MT, Elhanafy E, Daous HE, Huyen NT, Yamazaki W, Okabayashi T, Abe M, Norimine J, Sekiguchi S (2021) Identification of *Escherichia coli* and Related Enterobacteriaceae and examination of their phenotypic antimicrobial resistance patterns: a pilot study at a wildlife-livestock interface in Lusaka. Zambia Antibiotics 10(3):238. https://doi.org/10.3390/antibiotics10030238
Kariuki S, Kering K, Wairimu C, Onsare R, Mbae C (2022) Antimicrobial resistance rates and surveillance in sub-Saharan Africa: Where are we now? Infect Drug Resist 15:3589–3609. https://doi.org/10.2147/IDR.S342753
Kashoma IP, Kassem I, Kumar A, Kessy BM, Gebreyes W, Kazwala RR et al (2015) Antimicrobial resistance and genotypic diversity of campylobacter isolated from pigs, dairy, and beef cattle in Tanzania. Front Microbiol 6:1240. https://doi.org/10.3389/fmicb.2015.01240
Kiiru S, Maina J, Katana J, Mwaniki J, Kiiru J (2022) Bacterial etiology of urinary tract infections in Kenyan health facilities and resistance towards commonly used antibiotics. medRxiv 10.25.22281521. https://doi.org/10.1101/2022.10.25.22281521
Lord J, Gikonyo A, Miwa A, Odoi A (2021) Antimicrobial resistance among *Enterobacteriaceae*, *Staphylococcus aureus* and *Pseudomonas* spp. isolates from clinical specimens from a hospital in Nairobi, Kenya. Peer J 9:e11958. https://doi.org/10.7717/peerj.11958
Mainda G, Bessell P, Muma J, McAteer SP, Chase-Topping M, Gibbons J et al (2015) Prevalence and patterns of antimicrobial resistance among *Escherichia coli* isolated from Zambian dairy cattle across different production systems. Sci Rep 5:12439. https://doi.org/10.1038/srep12439
Manyahi J, Kibwana U, Mgimba E, Majigo M (2020) Multi-drug resistant bacteria predict mortality in bloodstream infection in a tertiary setting in Tanzania. PLoS ONE 15(3):e0220424. https://doi.org/10.1371/journal.pone.0220424
Manyahi J, Majigo M, Kibwana U, Kamori D, Lyamuya EF (2022) Colonization of extended-spectrum β-lactamase producing Enterobacterales and methicillin-resistant *S. aureus* in the intensive care unit at a tertiary hospital in Tanzania: implications for Infection control and prevention. Infect Prev Pract. https://doi.org/10.1016/j.infpip.2022.100212
Moore CC, Jacob ST, Banura P, Zhang J, Stroup S, Boulware DR et al (2019) Etiology of sepsis in uganda using a quantitative polymerase chain reaction-based TaqMan array card. Clin Infect Dis. https://doi.org/10.1093/cid/ciy472
Mshana SE, Sindato C, Matee MI, Mboera LEG (2021) Antimicrobial use and resistance in agriculture and food production systems in Africa: a systematic review. Antibiotics 10(8):976. https://doi.org/10.3390/antibiotics10080976
Muhindo R, Joloba EN, Nakanjako D (2016) Health management information system (HMIS); whose data is it anyway? Contextual challenges. Public Manag Rev 4(2):2. https://doi.org/10.4172/2315-7844.1000190
Mutai WC, Mureithi MW, Anzala O, Revath G, Kullin B, Burugu M et al (2021) High prevalence of multidrug-resistant *Clostridioides difficile* following extensive use of antimicrobials in hospitalized patients in Kenya. Front Cell Infect Microbiol. https://doi.org/10.3389/fcimb.2020.604986
Mutua JM, Njeru JM, Musyoki AM (2022) Multidrug resistant bacterial infections in severely ill COVID-19 patients admitted in a national referral and teaching hospital, Kenya. BMC Infect Dis 22:877. https://doi.org/10.1186/s12879-022-07885-3
Mwanyika G, Call DR, Rugumisa B, Luanda C, Murutu R, Subbiah M, Buza J (2016) Load and prevalence of antimicrobial-resistant *Escherichia coli* from fresh goat meat in Arusha, Tanzania. J Food Prot 79(9):1635–1641. https://doi.org/10.4315/0362-028X.JFP-15-573
Obakiro SB, Kiyimba K, Paasi G, Napyo A, Anthierens S, Waako P, Royen PV, Iramiot JS, Goossens H, Kostyanev T (2021) Prevalence of antibiotic-resistant bacteria among patients in two tertiary hospitals in Eastern Uganda. J Glob Antimicrob Resist. https://doi.org/10.1016/j.jgar.2021.02.021
Omulo S, Lofgren ET, Lockwood S et al (2021) Carriage of antimicrobial-resistant bacteria in a high-density informal settlement in Kenya is associated with environmental risk-factors. Antimicrob Resist Infect Control. https://doi.org/10.1186/s13756-021-00886-y
Peng XZ, Ou WH, Wang C, Huang QX, Jin JB, Tan JH (2014) Occurrence and ecological potential of pharmaceuticals and personal care products in ground water and reservoirs in the vicinity of municipal landfills in China. Sci Total Environ 490:889–898. https://doi.org/10.1016/j.scitotenv.2014.05.068
Schar D, Sommanustweechai A, Laxminarayan R, Tangcharoensathien V (2018) Surveillance of antimicrobial consumption in animal production sectors of low- and middle-income countries: optimizing use and addressing antimicrobial resistance. PLoS Med 15:e1002521. https://doi.org/10.1371/journal.pmed.1002521
Seale AC, Hutchison C, Fernandes S, Stoessen K, Stabler RA, Scott JA (2017) Supporting surveillance capacity for antimicrobial resistance: Laboratory capacity strengthening for drug resistant infections in low and middle income countries. Welcome Open Res 2:91. https://doi.org/10.12688/wellcomeopenres.12523.1
Shawa M, Furuta Y, Paudel A, Kabunda O, Mulenga E, Mubanga M, Kamboyi H, Zorigt T, Chambaro H, Simbotwe M, Hang'ombe B, Higashi H (2022) Clonal relationship between multidrug-resistant *Escherichia coli* ST69 from poultry and humans in Lusaka, Zambia. FEMS Microbiol Lett 368(21–24):fnac004. https://doi.org/10.1093/femsle/fnac004
Siahaan S, Herman MJ, Fitri N (2022) Antimicrobial resistance situation in Indonesia: a challenge of multisector and global coordination. J Trop Med. https://doi.org/10.1155/2022/2783300
Tadesse BT, Ashley EA, Ongarello S et al (2017) Antimicrobial resistance in Africa: a systematic review. BMC Infect Dis 17:616. https://doi.org/10.1186/s12879-017-2713-1
Tompkins K, Juliano JJ, van Duin D (2021) Antimicrobial resistance in *Enterobacterales* and its contribution to sepsis in sub-Saharan Africa. Front Med. https://doi.org/10.3389/fmed.2021.615649
van Belkum A, Bachmann TT, Lüdke G et al (2019) Developmental roadmap for antimicrobial susceptibility testing systems. Nat Rev Microbiol 17:51–62. https://doi.org/10.1038/s41579-018-0098-9
World Health Organization (2017) Joint external evaluation of IHR core capacities of the Republic of Kenya. https://apps.who.int/iris/handle/10665/258694.
Zachariah OH, Lizzy MA, Rose K et al (2021) Multiple drug resistance of *Campylobacter jejuni and Shigella* isolated from diarrhoeic children at Kapsabet County referral hospital, Kenya. BMC Infect Dis 21:109. https://doi.org/10.1186/s12879-021-05788-3

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