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Effectiveness of Surveillance Systems in Combating Anthrax Outbreaks in Africa: A Systematic Review

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ABSTRACT

Introduction: Anthrax outbreaks remain a recurring public health concern in Africa, posing threats to both human and animal populations. The objective of the systematic review was to evaluate the effectiveness of surveillance systems in combating anthrax outbreaks in the region.
Methods and materials: The review covers a period from 2014 to 2024, focusing on key factors such as epidemiological surveillance, intersectoral collaboration, and outbreak response strategies. The literature search identified 29 peer-reviewed articles, including case control, cross-sectional, qualitative inquiries and legislative documents, providing insights into the strengths and weaknesses of existing surveillance systems.
Results: The review emphasizes the importance of integrated surveillance systems that bridge human, animal, and environmental health sectors for comprehensive monitoring and risk management. Several challenges were identified, such as technical shortcomings in sectoral surveillance, inadequate funding for integrated surveillance, and fragmented governance structures. The lack of coordination between different programs and limited collaboration hindered the efficiency of surveillance efforts. Case studies from Burkina Faso, Zimbabwe, Nigeria, and Kenya highlight the varying approaches and outcomes in combating anthrax outbreaks. While some regions demonstrated effective surveillance through electronic Integrated Disease Surveillance Response (e-IDSR) systems, others faced obstacles with paper-based systems and insufficient resources.
Conclusion: In conclusion, this systematic review underscores the need for enhanced surveillance capacities, intersectoral collaboration, and resource mobilization to effectively combat anthrax outbreaks in Africa. The findings provide valuable insights for policymakers, health authorities, and other stakeholders involved in anthrax prevention and control efforts.

Key words: Surveillance, Anthrax, Awareness, Outbreaks, Multisectoral

INTRODUCTION

The recurrence of anthrax outbreaks in many parts of the world warrants more attention for heightened awareness and effective control measures to prevent anthrax infection in animals and limit its transmission to humans. It is necessary in an endemic country, or any region that may have conditions conducive to

anthrax outbreaks or a history of outbreaks, to maintain vigilance to prevent, detect and respond to outbreaks in those regions, as they may recur in those areas after an absence of several years or more [1]. The primary reservoir for anthrax is the soil. Grazing animals become infected when they ingest B. anthracis spores on vegetation in an area where the soil or water sources are contaminated by the spores [2].Environmental factors such as temperature and precipitation patterns are among the main determinants for the onset of anthrax outbreaks including prolonged periods of hot, dry weather that follow heavy rains and flooding, or with the onset of rains ending a period of drought; therefore, anthrax outbreaks may have a seasonal pattern [3]. Other factors that may trigger outbreaks include the disruption of the soil through tillage or excavation, or by landslides or dust storms.

The effectiveness of surveillance systems in combating anthrax outbreaks in Africa is crucial [4]. Surveillance plan for anthrax in humans following a pre-emergency outbreak and post-outbreak phase must be carried out especially in humans [4]. This must be based on epidemiological risk assessment and on the basis of history of contact, consumption and trade of animal products of the animals suspected to have died of anthrax [5]. The specific objective for this systematic review is to assess the effectiveness of surveillance systems in combating anthrax outbreaks in Africa.

BACKGROUND

Anthrax is a zoonotic disease of public health significance, associated with human and livestock morbidity and mortality as well as economic losses due to decreased trade in livestock and derived produce due to prohibition of movement of animals and products of animal origin during quarantine. The disease is caused by a gram-positive, spore-forming rod-shaped bacteria, *Bacillus anthracis* (B. anthracis). A carcass of previously infected animals can contaminate soil thus making the contaminated soil serve as a natural reservoir for anthrax spores [6]. The disease affects both livestock and Human health and if not controlled and managed can be fatal [4]. There are four main types of anthrax in humans, which are classified by the route of infection: cutaneous (most common), gastrointestinal, respiratory, and (more recently) injectional anthrax [7].

Anthrax continues to be a disease of public health importance in Zimbabwe since sporadic outbreaks are reported annually in many parts of the country [1]. Human behavior has been implicated in this transmission [8]. These include microorganisms adapting to climate and weather changes, shifting ecosystems, and human susceptibility to infection due to immunosuppression, malnutrition, and poor immunization [9].

The persistence of anthrax within the West and Central Africa Sub-region (Benin, Burkina Faso, Ghana, Niger, and Togo) has been attributed to factors specific to the prevailing environmental conditions, inadequate vaccination services, absence of proper disposal methods for infected animal carcasses and socio-cultural practices at the community level, such as the slaughter of sick animals or the butchering of dead animals for salvage purposes, as well as the consumption or handling of meat from infected animals, contribute to recurrent cases of anthrax in humans [5]. In Kenya, the outbreak in Kisumu East Sub County and in a remote village in Trans Mara East sub-county, Narok County, southern Kenya, originated from the consumption of potentially contaminated beef [10]. The local community described the disease as *"burasta*" loosely translated to mean curse of sudden death in livestock [11].

Epidemiological surveillance is based on the systematic and continuous collection of data to monitor the health status and risk factors of a defined population with the objective of compiling and analyzing them, and then to

disseminate timely information that contributes to the planning, implementation and evaluation of risk-management measures. Epidemiological surveillance of zoonotic diseases requires the establishment of integrated surveillance systems that bring together the surveillance programs operating in the human, animal, and environmental sectors in order to improve the information produced and its use for better health management [4].

It is critical to discuss the existing national anthrax surveillance systems' strengths, weaknesses, and barriers, with a focus on anthrax case definitions, case reporting processes, surveillance data quality, outbreak investigation protocols, and intersectoral collaboration, which provide valuable information on areas for collaboration and project development to enhance anthrax surveillance [12]. During the disease outbreak response, the role of National level is to identify and characterize the outbreak etiologic agents, monitoring the progress of the outbreak and putting the effectiveness of control and preventive strategies in place, regular analysis of diagnostic and surveillance data from livestock and wildlife are essential for efficient management of anthrax outbreaks in animals and protecting human population [13].

Enhancing outbreak response and surveillance capacity directly affects the country's ability to detect and contain anthrax outbreaks and Development of standard operational procedures for specimen collection and transportation, as well as establishment of laboratory diagnostics that are reliable, appropriate, safe, and sustainable, are necessary steps for enhancing anthrax surveillance [12]. Intersectoral collaboration for the governance and implementation of surveillance activities, including integration of data and sharing of information on animal, human and environmental health, is increasingly seen as key to efficient health systems [4].

In Burkina Faso, zoonoses surveillance, including anthrax, is an official mission carried out by health authorities, namely the Ministry of Health (MOH), the Ministry of Animal Resources and Fisheries (MARF), and the Ministry of the Environment, Green Economy and Climate Change [4].

Surveillance during the pre-emergence and for prevention phase should comprise of clinical and laboratory surveillance in high-risk areas and when there is imminent threat of anthrax incursion. The reporting should be done as per the notifiable diseases surveillance reporting system. Clinical disease surveillance is aimed at detection of anthrax cases based on clinical signs and symptoms of anthrax at the individual/household level and health centers. Anthrax should be suspected when any patient is found or visit health centers with cutaneous lesion on hand, legs, face and neck, abdominal distress characterized by nausea, vomiting, and anorexia, respiratory distress syndrome and acute encephalitis syndrome with history of exposure to anthrax suspected animals or/ and their products [13]. Targeted surveillance in human is recommended only in the high-risk areas or households where incidents of animal anthrax have been reported in the past and in those people, who handle meat and meat products (e.g. butchers, slaughterhouse workers). [10].

This review aims to assess the effectiveness of surveillance systems to combat anthrax outbreaks in Africa in view of the many complex public health intervention packages developed by various players in Africa in their quest to eliminate human anthrax. The strategic plan is to engage governments, state players, civil society groups, non-governmental organizations, diverse professionals of public health, and animal experts across Africa, for baseline and endline surveys. After these baseline assessments, a strategic surveillance system that would provide effective intervention and capacity building would be established for the training

of stakeholders from the departments of health, veterinary, forest, academic and allied health institutions.

METHODS

To assess the effectiveness of surveillance systems in combating anthrax outbreaks in Africa, a systematic review was conducted through a comprehensive search in electronic journal databases including PubMed Central, Web of Science, Scopus, and African Journals Online (AJOL), to identify relevant studies published between 2014 and 2024. The search terms included "Anthrax Surveillance", "Anthrax", "Surveillance", "Outbreak", "Africa" and related terms.

Table 1: Inclusion and exclusion criteria

Criterion	Inclusion	Exclusion
Content	All anthrax surveillance research	Any publication not related to anthrax
Context	Africa	Any publication outside Africa
Language	English	Any publication in other languages
Timeframe	2014-2024	Any publication outside the set timeframe
Type of Studies	Qualitative	Quantitative

Search strategy

The above broader topic was broken down to specific areas using the Population, Intervention/Indicator, Comparison, Outcome and Timeframe (PICOT as follows:

Population:

……

Intervention/Indicator:

……

Outcome:

……

Timeframe:

……

Data Extraction Assessment

Screening of Studies

Publications identified through different databases were downloaded and screened following the Preferred Reporting Items for Systematic reviews and Meta analyses (PRISMA).

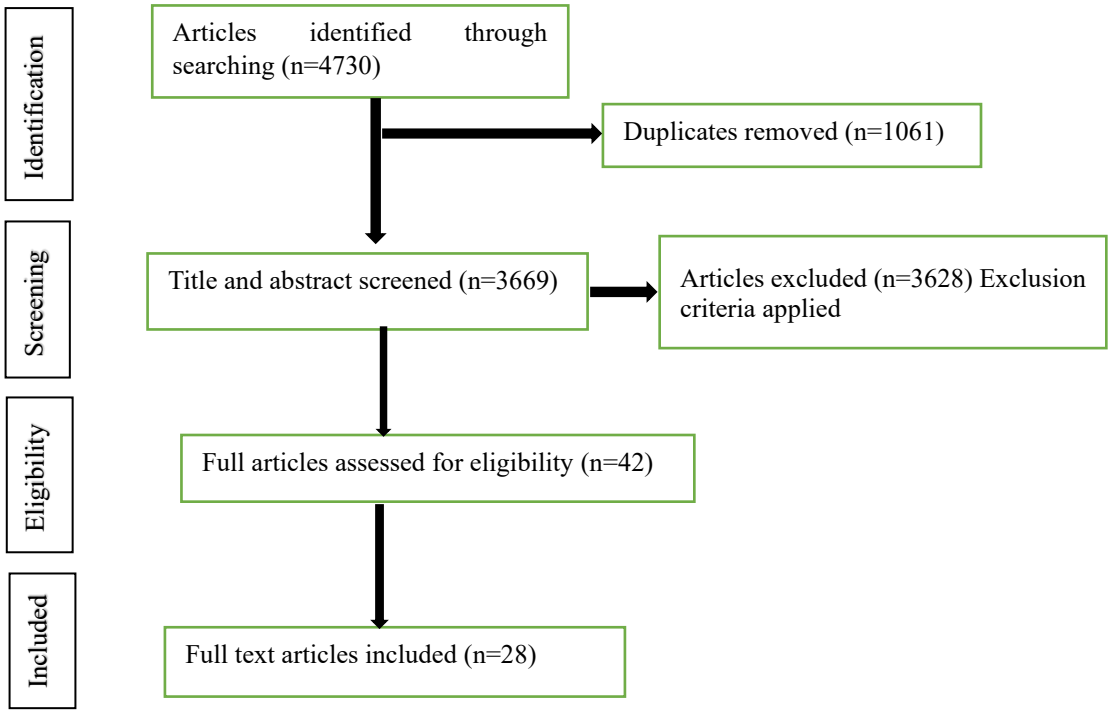

Figure 1: PRISMA Flow Diagram

Table 2: Description of study characteristics included in the Systematic Review

S/N	Author(s)	Year of Publication	Titles	Location	Study Design	Study Population	Results
1	John Gachohi, Bernard Bett, Fredrick Otieno, Eddy Mogoa, Peris Njoki	2022	Anthrax hotspot mapping in Kenya support establishing a sustainable two-phase elimination program targeting less than 6% of the country landmass	Kenya	Retrospective and Prospective Cross-Sectional Study	1043	Shows the point locations of livestock anthrax outbreaks obtained from field characterization of reported outbreaks (2017–2018) and active surveillance effort (2019–2020).
2	Sougrenoma Désiré Nana Jean Hugues Caffin, Raphaël Duboz1, Nicolas Antoine Moussiaux,	2022	Towards an integrated surveillance of zoonotic diseases in Burkina Faso: the case of anthrax	Burkina Faso	Qualitative descriptive analysis	29 Informants and 36 Documents	Analysis of the discourse of key stakeholders led to the identification of four categories of factors that may influence the implementation of an integrated surveillance system in the country: knowledge; technical, organizational and social capacities; motivation; intersectoral governance.
3	Stephen J, K, Assenga J, Jubilate B, Eblate E, Mwakapeje, E, Mghamba J, Chinyuka H, Kambarage D	2022	After-action review of rabies and anthrax outbreaks multisectoral response in Tanzania, challenges and lessons	Tanzania	cross-sectional surveys with participatory approach.	N/A	Lack of funds to carry out active disease investigation and paper-based disease surveillance system in animal sector were also a major challenge coupled with uncoordinated lack of PEP vaccines in district and regional hospitals as a result of high costs of maintaining the cold chain.
4	Richard Makurumidze, Notion Tafara Gombe,	2021	Investigation of an anthrax outbreak in	zimbabwe	Case-control	66	In These recurrent challenges predominantly

	Tapuwa Magure and Mufuta Tshimanga		Makoni District, Zimbabwe				occur between January and May, aligning with the dry and early wet seasons. The continued prevalence of anthrax in the region can be attributed to factors such as the pathogen's resilience in the soil, specific environmental conditions, and the absence of adequate vaccination services and proper disposal methods for infected animal carcasses.
5	Hammed O. Mogaji, Babatunde Adewale, Stella I. Smith, Ehimario U. Igumbor, Chidumebi J. Idemili and Andrew W. Taylor Robinson G.	2024	Combatting anthrax outbreaks across Nigeria's national land borders: need to optimize surveillance with epidemiological surveys	Nigeria	Epidemiological surveys.	999 Susceptible Population	Molecular diagnostics and Interdisciplinary action are required
6	Moyo E, Mhango M, Moyo P, Dzinamarira T, Chitungo I, Murewanhema	2023	Emerging infectious disease outbreaks in Sub-Saharan Africa: Learning from the past and present to be better prepared for future outbreaks	Sub Saharan Africa	Qualitative	N/A	Regular surveillance of animal handlers is critical in preventing emerging infectious disease outbreaks.
7	Doreen Chilolo Sitali, Chisoni Mumba, Eystein Skjerve, Oliver Mweemba, Consolata Kabonesa, Mwinyi Omary Mwinyi, Luke Nyakarahuka, John Bwalya Muma	2017	Awareness and attitudes towards anthrax and meat consumption practices among affected communities in	Zambia	Cross sectional survey	64	Awareness of anthrax varied across communities. Qualitative findings also indicated that, in Western and Muchinga provinces, human anthrax was transmitted by eating infected beef and hippo

			Zambia: A mixed methods approach				(Hippopotamus amphibious) meat, respectively
8	Mwakapeje ER, Høgset S, Fyumagwa R, Nonga H E, Mdegela RH, Skjerve E.	2018	Anthrax Outbreak in the Humans-livestock and wildlife interface areas of Northern Tanzania: A retrospective record review 2006 to 2016	Tanzania	Retrospective Cross Sectional	Ministry of Health, Livestock and wildlife Informants	More Anthrax cases were recorded in the books despite the disease cases not included in the HMIS and IDSR reporting forms at the time of the research.
9	Viera, R A, Saizer, J S, Traxier R, M, Hendricks A K, Kadzik M E, Marston C K, Kolton C B, Stoddard R A, Bower A W	2017	Enhancing Surveillance and Diagnostics in Anthrax - Endemic Countries	Ghana, Mali, Cameroon	Prospective Cross-sectional Study	N/A	Lack of integrated and multisectoral approach enhanced surveillance, Outbreak Response and diagnostic Capacity has a negative effect in combating Anthrax.
10	Bernard Chege Mugo, Cornelius Lekopien and Maurice Owiny	2021	An assessment of knowledge, attitude and practices on anthrax during an outbreak, Kisumu, Kenya, 2019	Kenya	Cross-sectional study	Households keeping livestock in the selected villages and those whose household head or any person above the age of 18 years was available	This research investigates an anthrax outbreak in Kisumu East Sub County, Kenya, highlighting the extent, associated factors, and community KAP towards anthrax. The study reveals significant gaps in knowledge and practices, emphasizing the importance of tailored interventions for effective prevention and control of anthrax outbreaks in the region.
11	Romha G & Girmay W	2020	Knowledge, attitude and practice towards anthrax in northern	Northern, Ethiopia	Cross-Sectional Study	862 participants, with 800 community members and 62	This research in Eastern Tigray, Northern Ethiopia, assesses the KAP of communities towards anthrax, revealing low levels

			Ethiopia: a mixed approach study			health professionals	of understanding and inconsistent knowledge. The study emphasizes the importance of continuous and comprehensive education to improve awareness and implement effective preventive measures against anthrax outbreaks in the region.
12	Mukarati NL, Matope G, de Garine-Wichatitsky M, Ndhlovu DN, Caron A, Pfukenyi M, D	2020	Pattern of anthrax at the wildlife livestock human interface in Zimbabwe.	Zimbabwe	Questionnaire	Ministry of Health and Child Care, Zimbabwe parks and wildlife management authority	a total of 3516 anthrax cases were recorded in the study in animals, with wildlife having 86.7% representing 3050/3516. livestock anthrax outbreak at non interface sites contributed 59.5% of outbreaks Department of Epidemiology and Disease Control livestock owners
13	Oduoye M.O, Scott G.Y, Dave T, Bolanle A.H, Mwinbong D. A, Modupeoluwa O.	2023	One health approach to mitigate anthrax in Ghana	Ghana	N/A	83 Human cases	The consequences of anthrax outbreaks, such as severe illness, economic losses, and social distress, are outlined. To combat this complex issue, the letter emphasizes the importance of enhanced awareness, prevention, accurate diagnosis, and timely treatment.
14	Saleh, F., Kitau, J., Konradsen, F. Leonard E. G. Mboera & Karin L. Schiøler	2021	Assessment of the core and support functions of the integrated disease surveillance and	Tanzania	Cross sectional survey	10 districts of Zanzibar and 45 public and private health	The performance of the IDSR system in Zanzibar was suboptimal particularly with respect to early detection of epidemics. Weak laboratory capacity at

			response system in Zanzibar, Tanzania				all levels greatly hampered detection and confirmation of cases and outbreaks.
15	Malik O. Oduoye | Godfred Y. Scott | Tirth Dave |Akanbi-Hakeem H. Bolanle | Alexandra D. Mwinbong | Olajide O. Modupeoluwa.	2023	Anthrax bio-surveillance of livestock in Arua District, Uganda	Uganda	Mixed Method study	57 community herds of livestock	The study conducted in Arua District confirmed the presence of anthrax in biological samples, with cattle being the most affected among reared species like goats and sheep. Key factors contributing to the spread of anthrax included lack of awareness among cattle owners and the community, scarcity of livestock vaccine, social norms, cultural practices, environmental factors, and poverty. The uncontrolled grazing system facilitated transmission and maintenance of anthrax outbreak cycles in Arua District and other regions in Uganda.
16	Nalishuwa.,K,W., Likwa,N,R.,, Munyeme,M and Hamoonga,T,E	2024	Knowledge, Attitude and Practice of Surveillance for Human Anthrax Among Veterinary and Health Professionals in Western Province of Zambia	Zambia	Cross-sectional study	203 study participants aged 18 years and above within selected districts of the study area.	The study highlights improved adherence to WHO standards in knowledge, attitudes, and practices regarding disease surveillance, yet identifies gaps in understanding surveillance components among professionals, influenced by factors like district location and profession type

17	Okello AL, Bardosh K, Smith J, Welburn SC	2014	One Health: Past Successes and Future Challenges in Three African Contexts	Nigeria, Tanzania Uganda	Qualitative case study	Key Informant Interviews (n = 32)	There is no 'one size fits all' approach to achieving the intersectoral collaboration, significant resource mobilization and political co-operation required to realize a One Health approach. Individual country requirements cannot be underestimated, dismissed or prescribed in a top-down manner.
18	Mbai JM, Omolo JO, Wamamba D, Maritim D, Gura Z, Obonyo M	2021	Assessment of knowledge, attitudes and practices towards anthrax in Narok County, Southern Kenya	Kenya	Quantitative study	334 respondents	There were differences in knowledge and practices towards anthrax by age-group and sex. Enhanced public health education and targeted interventions by relevant government agencies is recommended.
19	Getahun Bahiru, Abyot Bekele, Bewket Seraw, Lucy Boulanger and Ahmed Ali	2016	Human and animal anthrax in Ethiopia: A retrospective record review 2009-2013	Ethiopia	Quantitative	5,197 human and 26,737 animal anthrax cases	This data analysis revealed that a smaller number of human anthrax cases were reported than animal cases (ratio 1:5) in Ethiopia. The pastoralist areas where humans and animals co-exist closely did not report a single human case for the last five years.
20	Mangesho, PE, Neselle OM, Karimuribo E D, Mlangwa J E, Queenah K, Mboera, LE, Rushton J, Kock R, Hasler B & Rweyemamu M	2017	Exploring local knowledge and perceptions on zoonoses among pastoralists in northern and eastern Tanzania	Tanzania	Qualitative methods	223 people	Pastoralists from northern Tanzania possessed a higher understanding on the existence of a number of zoonoses than their eastern districts' counterparts.

21	Tschopp R & AGGiorgis, K	2024	Knowledge-attitude and practice of Anthrax and brucellosis: Implications for zoonotic disease surveillance and control in pastoral communities of Afar and Somali region, Ethiopia	Ethiopia	Two questionnaire surveys	509 pastoralists and 51 healthcare providers	This study revealed significant under-reporting of Anthrax and brucellosis, and weak prevention and response in humans, mostly associated with poor disease knowledge of healthcare providers. Ability to respond to animal outbreaks was limited by vaccine and drugs availability, timely vaccine administration and the mobility of pastoralists.
22	Joseph M. Kungu, Peninah Nsamba, Alfred Wejuli, John D. Kabasa	2020	Perceptions and Practices towards Anthrax in selected. Agricultural Communities in Arua District, Uganda	Uganda	Cross-sectional study	12 focus group discussions	This study shows that there is a knowledge gap about anthrax among the people in the affected communities. Key drivers for the anthrax outbreak such as poor cultural beliefs and practices and wildlife-livestock-human interactions were observed in all the three sub counties studied.
23	Peniah M, Munyua, M. Kariuki Njenga., Clinton O. Onyango, Austine O. Bitek, Marc-alain widow son	2019	Successes and challenges of the One Health approach in Kenya over the last decade	Kenya	N/A	N/A	Significant gaps remain in implementation of the One Health approach at subnational administrative levels; there are sustainability concerns, competing priorities and funding deficiencies.
24	Peter Ernest Mangesho, Moses Ole Neselle, Esron D. Karimuribo, James E. Mlangwa, Kevin Queenan, Leonard E.	2019	Comparative knowledge, attitudes, and practices regarding anthrax, brucellosis, and	Tanzania	Questionnaire	Interviewed residents (n = 388)	The combination of variable knowledge about zoonotic diseases in the three districts, reported occurrence of practices that are conducive to pathogen

	G. Mboera, Jonathan Rushton, Richard Kock, Barbara HaÈsler, Angwara Kiwara, Mark Rweyemamu		rabies in three districts of northern Tanzania				transmission, and previously documented circulation of pathogens causing anthrax, brucellosis and rabies in our study system, call for health education programs embedded in a holistic One Health approach.
25	Rea Tschopp, Ashenafi Gebre, Giorgis Kidanu	2022	A review on One Health approach in Ethiopia	Ethiopia	N/A	N/A	There are still so many challenges which need to be addressed. Poor integration among sectors in data sharing and communication, institutionalization of One Health, lack of continuous advocacy among the community, lack of financial funds from the government, limited research fund and activities on One Health, etc. are among many challenges.
26	Joseph M. Kungu, Peninah Nsamba, Alfred Wejuli, John D. Kabasa,	2023	The sporadic resurgence of anthrax in sub-Saharan Africa: intricacies and challenges to controlling a potentially fatal zoonotic disease	Sub-Saharan Africa	N/A	N/A	Limited access to diagnostic facilities and the scarcity of trained personnel impedes accurate diagnosis and often result in misdiagnosis.
27	John, L., Shekede, M.D., Gwitira, I. *et al*	2024	Modelling climate change impacts on the spatial distribution of anthrax in Zimbabwe.	Zimbabwe	N/A	N/A	The results showed that under current bioclimatic conditions, eastern and western districts of Zimbabwe were modelled as highly suitable, central districts moderately suitable and southern parts

							marginally suitable for anthrax occurrence. Future predictions demonstrated that the suitable (8%) and highly suitable (7%) areas for anthrax occurrence would increase under RCP4.5 scenario. In contrast, a respective decrease (11%) and marginal increase (0.6%) of suitable and highly suitable areas for anthrax occurrence were predicted under the RCP8.5 scenario. The percentage contribution of the predictors varied for the different scenarios; Bio6 and Bio18 for the current scenario, Bio2, Bio4 and Bio9 for the RCP4.5 and Bio3 and Bio15 for the RCP8.5 scenarios
28	Shandomy AE, Raizman, E et al	2016	Anthrax outbreaks: A Warning for Improved Prevention, Control and Heightened Awareness.	Benin, Burkina Faso, Ghana, Nigeria	N/A	N/A	

RESULTS

Among the 28 peer reviewed articles included in the final analysis: 12 Cross Sectional, 7 Qualitative Analysis, Epidemiologic surveys 4, Questionnaire, 4 Qualitative descriptive analyses and 1 Case Control. Burkina Faso, the quality of an integrated surveillance system depends to a large extent on the performance of each of its programmes, which in turn depends on the technical skills of the actors. We found the discourse of informants emphasized that sectoral surveillance in Burkina Faso has many technical shortcomings. They fall into four main categories: knowledge; capacity of actors; their motivation; and intersectoral governance. The quality of governance determines the capacity and knowledge levels of the system's actors, levels, which then have a retroactive effect on the proper functioning of governance mechanisms. Similarly, governance affects the motivation of actors to invest and commit to collaboration, which in turn contributes to the quality of governance. Also, the lack of funding for integrated surveillance is very clear in the results [4].

We identified different types of capacity that could impact on the implementation of an integrated surveillance system, namely technical, organizational and social. The quality of an integrated surveillance system depends to a large extent on the performance of each of its programmes, which in turn depends on the technical skills of the actors [10].

Anthrax outbreaks have occurred in Zimbabwe and Southern Kenya, demonstrating high morbidity and low mortality [14]. The outbreak in in Momba District, Songwe Region Tanzania as of March 30, 2021 had an estimated 5045 labor hours were spent on outbreak investigation and response activities by at least 29 district, region, zonal and national government employees across human, animal and environmental health sectors [15].

In some of the reviewed journal articles there has been a call to multi-sectoral approach by ministries in-charge of health, Livestock and wildlife approaches in the surveillance systems in order to combat this fatal disease. this integrated surveillance system will strengthen human, livestock and wildlife health in detecting, controlling and preventing Anthrax outbreaks in most African countries where resources are scarce [6].

Electronic Integrated Disease Surveillance Response (e-IDSR) system is well established in some of Africa; with cases being reported to the higher levels in real time. Conversely, the surveillance system in the animal health sector in Tanzania was mainly paper based and often takes time to reach Ministry of Livestock and Fisheries [16].

In order to control the escalation of anthrax cases in Nigeria, a multifaceted approach based on available surveillance data is imperative. Efforts should be directed towards curbing the disease in cattle, with a particular focus on national border districts. Community awareness interventions under a One Health approach should be instigated to educate pastoralist communities and livestock market traders on anthrax control and prevention [5]. Those who owned animals confirmed regularly vaccinating their livestock against anthrax, while a good number them have had slaughtered or skinned an anthrax infected dead animal. Still others admitted having treated sick animals by themselves. [11]. Regular surveillance of animal handlers is critical in preventing emerging infectious disease outbreaks. To improve early warning systems and emerging infectious disease outbreak detection, proactive animal handler surveillance can be an important addition to hospital surveillance [10]. There is a gross under-reporting of anthrax cases in existing human and animal surveillance systems, which can be an obstacle for estimating the real burden of anthrax in the hotspot districts [13]. Professional workers involved in anthrax

control indicated that most community members had negative attitudes towards not eating meat from moribund animals. Professional workers narrated that one of the challenges they faced in anthrax control was failure to convince community members against eating infected meat as infected meat can actually kill [9]. Past interventions in the affected area had included community education to prevent meat consumption of suspected animal anthrax cases. [11] Several achievements have been recorded so far (such as extension of one health schemes to the regional governments, joint disease surveillance and outbreak investigation activities, joint vaccination activities against zoonotic diseases, prioritization of zoonotic diseases, development of control and prevention strategic documents for different prioritized zoonotic diseases [17]. In Tanzania, Risk perceptions regarding different diseases varied across districts and were positively correlated with knowledge of the specific diseases, [18-19]. Most of the cattle that died in Zimbabwe were buried unsupervised and inappropriately. Animal carcasses were found in open spaces, which allowed dogs and vultures to consume them. [1].

In Zambia, the disease surveillance unit at the District Health Management Team institutes and leads further epidemiological investigations into any suspected and confirmed priority notifiable infectious disease and/or any public health event of concern with technical support from the respective Provincial Health Offices. [20]. The EHTs on the field had no modes of transport and personal protective equipment (PPE), i.e. overalls/work suits, gumboots, and heavy-duty gloves to use during the outbreak and were also not provided with allowances. Information, education, and communication materials were not available during the outbreak. Early stages of the outbreak response and only became available later. The district had no emergency preparedness and response plan, and the zoonotic committees were not functional [1]. Zambia faces a challenge in ensuring that the simple procedures of that is, recording and investigating any rumour of a suspected disease or events of public health concern, promptly recording, reporting and obtaining laboratory confirmation of any suspected priority notifiable infectious disease, and optimal utilisation of the IDSR technical guidelines at all levels of IDSR implementation was inconsistently being done. [20].

The team dispatched to institute the outbreak control measures comprised two EHTs, one veterinary officer, and a public health officer from the University of Zimbabwe, Field Epidemiology Training Programme. Health education was offered in primary and secondary schools in both. A total of 5896 people were reached with health education in both wards. Active case finding was conducted in the community, and a total of 8 more cases were identified. An outreach clinic to treat new cases and review old cases was established at Dope Secondary School in ward 22 wards [1].

Under the Ministry of Fisheries and Livestock in Zambia, surveillance is carried out by the Department of Veterinary Services. Veterinary assistants are involved in collecting animal related data which is transmitted to local veterinary offices. Part of their duties include carrying out vaccination campaigns not only during outbreaks but routinely for diseases like Anthrax which falls under diseases of national economic importance. For such diseases the government is responsible for the control of those diseases. Other diseases are management diseases where the farmer is responsible for prevention and control with government providing extension services. Anthrax falls under both with respect to control. That is because in Zambia, Anthrax is considered endemic in Eastern province, Western province and Chiawa area of Lusaka province. In those areas the government carries out routine vaccination programs annually between the

months of April and June [29]. However, unlike other diseases of national economic importance like Food and Mouth Disease where vaccinations are strictly done by the government, vaccines for Anthrax are readily available in Agro-shops where farmers can purchase and conduct their own vaccinations. Moreover, to help in the prevention of the disease, Anthrax vaccines are produced by the Central Veterinary Research Institute (CVRI), Balmoral in Lusaka for local farmers. The vaccines are sold from government offices.

The study conducted in Kenya 51% and 52% of the population had good knowledge of human and animal anthrax, respectively. Factors associated with good knowledge included rural residence, witnessing anthrax cases, and presenting cattle for vaccination [12]. Practices revealed that 23.2% would sell potentially contaminated beef, while 63.4% would bury or burn carcasses. Despite a high belief in vaccination effectiveness (93.8%), only 5.4% presented livestock for vaccination [21]

DISCUSSION

This systematic review presents stakeholder engagement in combating anthrax, the efficiency of surveillance systems, control and mitigation measures in Africa. The surveillance system includes three programmes, respectively, in the animal, human and environmental health sectors. Despite the establishment of new collaborative mechanisms and the influence of the TFPs, there is very little collaboration between these programmes in a One Health spirit. Collaboration is formalized at the central level via an inter-ministerial platform and its various bodies, but is not yet completely functional. At the local level, collaboration is not formalized but is effective between field agents in terms of information exchange and joint investigations. They fall into four main categories: knowledge; capacity of actors; their motivation; and intersectoral governance. However, these categories are not compartmentalized and links exist between their constituent factors. Intersectoral governance appears to be the element that structures all the factors. Indeed, the quality of governance conditions the capacity and knowledge levels of the system's actors, levels, which then have a retroactive effect on the proper functioning of governance mechanisms. Similarly, governance affects the motivation of actors to invest and commit to collaboration, which in turn contributes to the quality of governance [4].

Previous efforts to control anthrax outbreaks in endemic regions included mass vaccination of livestock, quarantine of infected animals, burning or burying of animal carcasses, and sensitization of the community. While most people know the threat of anthrax, yet entrenched behaviors, beliefs and cultural practices are a big challenge to mindset change toward the disease. [22]. The results do suggest that societal human behaviour played a key role in transmission of anthrax outbreaks [11]

The study in Arua district identified key drivers for anthrax outbreaks, including poor cultural beliefs and wildlife-livestock-human interactions. Raising awareness and promoting interdisciplinary collaboration are critical to addressing these issues [23-24].

It led to a deeper and richer understanding of the technical, cultural and socio-political factors that hamper the operationalization of integrated surveillance. Intersectoral health governance in Burkina Faso appears fragmented and still unable to lead actors towards a shared vision or a definition of strategic priorities that are feasible and collectively validated for integrated zoonotic disease surveillance [4].

Effectively addressing anthrax outbreaks in Nigeria therefore requires comprehensive strategies that emphasize understanding the current transmission status, animal movement patterns, and the broader socio-economic context in which pastoral herders operate [5].

Epidemiological surveys employing more refined molecular diagnostic approaches are required for identifying circulating strains and investigating phylogenetic linkages. Additionally, these surveys could be complemented by conducting serological assays that examine previous exposure and associated risk factors among animals and human populations living in communities situated along the borders of Nigeria, or locations where past outbreaks have occurred. Such research is important to enhance understanding of local contexts driving pathogen transmission and/or disease outbreak, prepare for future outbreaks and to identify the contributing factors facilitating transmission [5].

Awareness

Understanding of the susceptibility of animals and humans to anthrax, the signs and symptoms of anthrax in dead animals and sick human beings, seasonal outbreak periods, common transmission routes and the importance of vaccination as a preventive measure. However, focus group discussions revealed that some communities had poor understanding of the disease [8]. Widespread enlightenment campaigns on the potential danger of anthrax and the need to observe precautionary measures. It is imperative to point out that more research on anthrax is needed, especially in sub-Saharan Africa to better understand the molecular pathogenesis, as well as the interaction between its host and environment for proper precautionary step [25]. Telecommunication firms have also been employed by countries such as So Tom´e and Principe, Zambia, Nigeria, and Burkina Faso to promote the distribution of information about preventive and control methods. [14]

The outbreak in Zimbabwe was prolonged, and it took time for the district to start instituting outbreak control measures since the district did not have an emergency preparedness and response plan in addition to unavailability of adequate resources such as PPE. However, despite the delay in instituting control measures, the outbreak was brought under control within 2 months of laboratory confirmation of the first animal case and as soon as the district started to institute outbreak control measures [1]. The massive health education and awareness campaigns conducted could have also significantly contributed to curbing the outbreak. And is likely to have a positive impact in preventing outbreaks. Clearly this calls for concerted efforts at mobilization of resources and multidisciplinary stakeholders' collaboration under one health banner for effective surveillance and control of anthrax in animals and humans [21]. The availability of multisector costing data recorded and analysed in the OCT can be shared with appropriate stakeholders to be used as a baseline to estimate costs to guide preparation for future anthrax [15].

Capacity building for routine data analysis, supportive, supervision, sensitizations as well as provision of logistics support and guidelines for data management and analysis at each level need to be prioritized [26].

From 2001 to 2022, 33% of public health emergencies were zoonotic disease outbreaks, 30% by dengue fever, anthrax, plague, monkey pox, and others. A growing population driving greater demand for animal-derived food is associated with zoonotic disease outbreaks. Population growth and urbanization have reduced wildlife habitats [9].

Lack of funds to carry out active disease investigation and paper-based disease surveillance system in animal sector were also a major challenge coupled with uncoordinated lack of PEP vaccines in district and regional hospitals as a result of high costs of maintaining the cold chain. In addition, there are lack of routine vaccination programmes for rabies and anthrax because of fragmented veterinary service supply chain and the resources to enable disease investigation and

responses are lacking because of heavy reliance on donor support [16].

One Health approach recognizes that human health is dependent on the health of animals, plants, and their shared environment. It emphasizes communication, coordination, and collaboration among professionals in the human, animal, and environmental sectors, as well as other relevant disciplines to mobilize resources and implement control measures to control diseases. Although it is very difficult to eradicate anthrax owing to the persistence of anthrax bacterial spores in the environment, it can be prevented, which can only be achieved using the holistic framework of the One Health approach for the prevention, detection, and effective response to the disease outbreak. To prevent zoonotic diseases, including anthrax, the One Health approach advocates for vaccination of animals to help prevent the spread of the disease to humans and protect individuals at high risk. education and awareness campaigns are very important to inform communities about the risk, transmission pathways, and preventive measures to curb anthrax, which includes proper disposal of infected carcass animals. The success of the One Health program implemented towards anthrax control in many African countries include; ensuring a multidisciplinary and interdisciplinary collaboration among the physicians, nurses, pharmacists, veterinarians, including animal scientists and social workers in mitigating anthrax outbreak, ensuring animal vaccination, prompt diagnosis and treatment of the victims and limiting complications that could arise from the disease. It would also provide one health job opportunities, diversities among the health workers and improve the economic development a country. [7].

Ethiopia has achieved considerable One Health approach activities to push forward the Global Health Security Agenda (GHSA) commitments and to prevent, detect, and respond to existing and emerging Anthrax threats since the 2000s. It has already established a National One Health Steering Committee (NOHSC) and Technical Working Groups (TWG) with a five-year strategic plan for the period 2018–2022, [17, 24]. The combination of variable knowledge about zoonotic diseases in the three districts of Tanzania, reported occurrence of practices that are conducive to pathogen transmission, and previously documented circulation of pathogens causing anthrax, call for health education programs embedded in a holistic One Health approach [18].

Improvements to Combat Outbreak of Anthrax

There is a lot of effort that can be done to control anthrax in wildlife in Africa. Surveillance, reporting systems and outbreak response Coordination, collaboration, Education Campaigns, Anthrax Vaccines Africa anthrax network, Research and policies Advocacy for resource mobilization, Diagnostics & laboratory capacity [27]. There must be Optimization of surveillance systems with mult-sectoral integration in order to improve surveillance coverage and quality.

For large populations, incident command should alert the public about the location of clinical centres for treatment or PEP through media announcements. Conduct regular surveillance of all exposed individuals for the appropriate incubation period [27].

This will enhance early detection and detection of potential new pathogens such as zoonotic diseases as well as increase knowledge of the epidemiological aspects the disease and the zoonoses which potentially have high mortality [6].

Application and implementation of the concepts of Integrated Disease Surveillance and Response (IDSR) strategy, coupled with Early Warning Alert and Response (EWAR) system using indicator-based and event-based surveillance mechanisms and guidance on how IDSR works, can facilitate the implementation

of the International Health Regulation (IHR) core capacities [28] engagement of stakeholders, define sources of information about health events in the community, identify community-based surveillance (CBS) focal persons, identify diseases the community is at risk of acquiring from IDSR priority list, define case or events or signals detection methods, disseminate data collection and reporting tools, define methods of reporting/communicating diseases, conditions and public health, train all key actors in the CBS system.

LIMITATIONS

First, the geographical focus on case studies from only a few African countries may limit the generalizability of the findings to other regions. Second, the review may be subject to publication bias, as only peer-reviewed articles were considered, potentially excluding relevant grey literature or unpublished studies. Additionally, the inclusion of diverse study designs (case-control, cross-sectional, and qualitative) introduces methodological heterogeneity, making it challenging to draw uniform conclusions. Furthermore, the lack of detailed quantitative analysis limits the ability to assess the overall impact of surveillance systems across different settings. Lastly, while the review highlights the benefits of electronic surveillance systems (e-IDSR), it does not thoroughly address the barriers faced by regions using paper-based systems.

CONCLUSION

Several countries do not have plans for epidemic preparedness and those who have committees are inactive with no meetings being held, thus the delayed institution of appropriate prevention and control measures. Despite managing outbreaks successfully, surveillance systems are not well established for early detection, reporting and responding to outbreaks and public health emergencies. The performance of both core and support surveillance functions is unsatisfactory and the surveillance workforce is inadequate coupled with limited finances.

Lack of strengthened multi-sectorial surveillance approach in planning and managing anthrax outbreaks contributes to the increased poor disease outcome as well as having negative impact on both human and animal health. Hence the call for strengthened collaboration amongst all involved stakeholder in combating anthrax outbreaks in Africa.

Authors' Contribution

Conception and design of the research: *GH, EK CC,*

Acquisition of data: *CC, IC, MH, LH, BC*

Analysis and interpretation of the data: *IC, LH, BC, CC, EK, NT*

Writing of the manuscript: *LH, GH, CC, MH, IC, EK, NT*

Critical revision of the manuscript for intellectual content: *LH, GH, CC, MH, IC, EK, BC, NT*

Approving the manuscript. *All*

Declaration by Authors

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