ISSN: 2474-3658

Rumide et al. J Infect Dis Epidemiol 2023, 9:310
DOI: 10.23937/2474-3658/1510310
Volume 9 | Issue 9
Open Access

Journal of
Infectious Diseases and Epidemiology

REVIEW ARTICLE

Anthrax Outbreak in Nigeria: An Issue for Concern?

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Abstract

Anthrax is a highly pathogenic zoonotic disease that is attributed to the aerobic, rod-like Gram-positive bacteria known as *Bacillus anthracis.* This disease primarily affects domestic and wild herbivores through the consumption of vegetation, water or soil and inhalation of air or dust contaminated with highly resistant *B. anthracis* spores. Humans become infected through inhalation, ingestion of animal and animal products, injection of hard drugs and cutaneous routes through contact with infected animals or carcasses. The outbreak of anthrax frequently occurs in regions with high levels of agricultural practices, including Africa and Asia. Although endemic in West Africa, Nigeria recorded her first anthrax case in July 2023, which led to the mortality of eight farm animals. Several factors may have contributed to this outbreak including changes in soil pH, moisture levels, porosity and texture and the recent outbreak in Ghana, a neighboring country. Strategies to control human anthrax infections are mostly tied to those that limit the occurrence of anthrax in animals and reduce human exposure to diseased/deceased animals or their byproducts. The most effective ways to prevent and treat animal anthrax are annual vaccination (preventive and ring), quarantine and use of antibiotics. Furthermore, it is important that public health and animal health institutions collaborate promptly on the detection of anthrax within a given area. This collaboration aims to enhance awareness among medical professionals, animal health practitioners, and those residing in the affected region.

Keywords

Anthrax, Outbreak, *Bacillus anthracis*, Nigeria, Infectious disease

Introduction

Anthrax is an acute zoonotic disease caused by the presence of an aerobic, rod-like Gram-positive bacteria known as *Bacillus anthracis* (CDC, 2016). These large spore-forming bacilli occur in short chains or single forms [1]. They are found in the soil as dormant spores, which persist for several years and become harmful only when activated within a living host [2]. These spores enter a host (primarily domestic and wild animals) by ingesting contaminated feed and soil (Welde, 2023). Humans become infected through inhalation, ingesting animal and animal-derived products like meat or dairy products, injection of hard drugs and cutaneous routes by contact with contaminated animals or carcasses [3].

Studies have shown anthrax outbreaks occur in rural regions with high dependence on agriculture for economic growth and sustenance [4]. These regions are mainly rural rain-fed areas across arid and temperate countries in Subsaharan Africa, Europe and North America [5]. The first anthrax incident in Nigeria was reported at a local farm in the Northern part of the country, making the disease a recent cause of public health concern [6]. Therefore, this review investigates the recent anthrax outbreak in Nigeria and its impact on public health.

Historical Perspective of Anthrax Outbreaks Worldwide

Anthrax is an ancient disease believed to have begun in Egypt and Mesopotamia around 700 BC [1]. Although the first clinical documentation of anthrax was published in bacill the 1700s, the study of the disease did not begin until the 1800s [7]. The identification of *Bacillus anthracis* as the causal agent of the disease was accomplished by Casimir Joseph Davaine and Pierre Raver in 1850, while a further study of its life cycle was conducted by Robert Koch in 1876 [3]. This study led to "Koch Postulates", which established the link between microbes, disease occurrence and transmission. Following this, the outbreak of anthrax has been

Citation: Rumide TS, Samuel E, Oni O (2023) Anthrax Outbreak in Nigeria: An Issue for Concern?. J Infect Dis Epidemiol 9:310. doi.org/10.23937/2474-3658/1510310

Accepted: September 28, 2023: **Published:** September 30, 2023

reported in several countries worldwide, including the USA, Australia, Pakistan, Kenya, Sweden, and Italy, amongst others [1].

Anthrax has been identified as the infamous disease known as the "black bane", which occurred in Europe in the 1600s and killed more than 60,000 cattle and humans. Likewise, there was a large outbreak in the Zimbabwean human population between 1979 and 1980, with approximately 10,000 cutaneous anthrax cases [8]. Furthermore, Siberia recorded a large outbreak of the disease in 2016, significantly reducing the reindeer population in the region and killing one human [9]. However, the most notorious impact of anthrax on humans was the 2001 terrorist attack in the US known as Amerithrax, which led to the infection of twenty-two people and the death of five [10]. This was one of the major demonstrations of anthrax as a bioterrorism weapon [11].

Recent reports of anthrax outbreaks have been recorded across the African continent. Anthrax is endemic in Kenya and is known as the most important zoonotic disease in the country (Muturi, et al. 2017). A study by Gachohi, et al. [12] showed that about 51 anthrax outbreaks have occurred in Kenya and are associated with > 1000 deaths across several wildlife conservation areas between 1999-2017. An unusual death of cows occurred in Ngenge, Uganda, after showing typical signs of anthrax disease, with 18 cows dead during the outbreak period (Mayania et al., 2018). As of June 2023, Ghana reported an anthrax outbreak and recorded about thirty human cases, over thirty-three animals, and one human dead (99Science, 2023). Similarly, Nigeria recorded the first anthrax case since the outbreak in Ghana, leading to eight farm animals' mortality [6].

Epidemiology and Transmission of Anthrax

The occurrence of anthrax has been reported in several countries. However, due to its sporadic occurrence, it has yet to be addressed in several regions worldwide [13]. This zoonotic disease is characterised by its severity and impact on both domestic and wild herbivores, including goats, pigs, cows, sheep, and deer, which may lead to the death of the animals if not properly treated (CDC, 2024). These animals are known as the primary hosts of the disease and become infected by consuming vegetation, water or soil and inhaling air or dust contaminated with highly resistant *B. anthracis* spores [14]. Humans are incidental hosts and are susceptible to infections via direct contact with diseased animals or by exposure to other sources of contamination such as animal feed, skin, milk, meat, and other similar materials [2]. Other routes include inhalation, ingestion and gastrointestinal [14]. Most cases in humans are cutaneous anthrax (95%-99%), with an incubation period of 1-12 days and more treatable compared to rare presentations such as injection anthrax, which is more difficult to treat and may lead to death if not detected and treated early [15]. Since anthrax is not transmissible, human transmission of anthrax is very unusual, with only suspected cutaneous transmission occurring due to contact with discharges from skin lesions of an infected individual [10].

According to Carlson, et al. [4], anthrax is an overlooked disease; thus, the incidence worldwide in humans and animals has been poorly characterised. Notwithstanding, Carlson, et al. [4] conducted global research to estimate the incidence of anthrax. The results showed that the global incidence of anthrax in humans was estimated at around 1.8 billion people, with an estimated 2,000 cases yearly. Most of these outbreaks are concentrated in highly endemic areas such as Africa, South America, Asia and some rural parts of Europe [5]. This may be due to the livestock population in these areas, estimated to be 1.1 billion at a 95% confidence interval, many of which were unvaccinated (an average of 198.2 million vaccine doses were administered yearly compared to 1.1 billion at risk) [4].

The global estimate of the prevalence of anthrax in livestock was 24% between 1992 and 2020 [16]. Africa had the highest prevalence, being endemic to anthrax. Sushma, et al. [16] opined that this occurrence was likely due to the region's high agricultural practices, livestock population and favourable environmental conditions. Other continents reported high prevalence include Europe (23%) and North America (21%). This global prevalence and variation are compounded by climate change, which contributes to the spread and survival of *B. anthracis* due to changes in each continent's average temperature, rainfall and soil characteristics. Hence, immigrants and refugees from and travellers to safari areas, rural regions with limited food processing capacity and low socioeconomic development are at a greater risk of contracting anthrax due to a higher possibility of contact with animals, carcasses and ingestion of poorly processed animals products.

Anthrax Incidents in Nigeria

Anthrax is a very virulent disease that may infect humans and animals. Several anthrax cases have been reported in different parts of Subsaharan Africa, causing the loss of thousands of cattle and wild animals [3]. Nigeria runs a large agriculture sector, contributing most of the nation's GDP [17]. Agriculture in Nigeria involves mainly agricultural production, livestock rearing, fishing, and forestry and remains the bedrock of the economy as it contributes an average of 24% to the GDP yearly [17].

Although endemic in West Africa, Nigeria recorded her first anthrax case in July 2023. This came a few weeks after the Ghana anthrax outbreak in June 2023 [18]. According to an official press release by the Federal Ministry of Agriculture and Rural Development (FMARD), suspicions of the disease arose on July 13, 2023, when eight cattle who were bleeding from external body openings died in a multi-specie farm located in Suleja LGA of Niger state [19]. One major feature of anthrax observed was the lack of clotting in the blood discharged from the animals [6]. To confirm the diagnosis, laboratory tests were conducted on animal blood samples by the National Veterinary Research Institute Laboratory in Jos Plateau state [20]. The positive test reports made the case the first reported in the country.

Subsequently, the Federal Government of Nigeria alerted the public of the outbreak and those in neighbouring countries [18]. Strategies have begun to curtail the spread of the disease, including mass vaccination of farm animals across several states [21]. On this note, the FMARD permanent secretary, Dr. Ernest Afolabi Umakhihe, has expressed the importance of public awareness campaigns to educate the public about the disease, its transmission mode, prevention and control [21]. He also emphasised the need for proper surveillance of markets, abattoirs, and slaughter zones to help identify the early onset of the disease and curtail further spread. Currently, not much is known about the outbreak in the country. However, investigations are underway to trace the source of the disease and determine factors that may have contributed to its occurrence.

Factors Contributing to Anthrax Outbreaks

Anthrax is a zoonotic disease, with the environment, animal hosts, and people all contributing to its spread and extent of infection [1]. According to Norris, et al. [22], the spores of *Bacillus anthracis* can remain dormant for an extended time before infecting a susceptible host. The Omberg anthrax epidemic proves that anthrax spores can persist in the environment for extended periods before an outbreak [9]. Numerous environmental factors contribute to the viability and dissemination of anthrax spores. Driciru, et al. [23] claim that soil conditions, including pH and moisture levels, may influence the viability and duration of spores. Previous research has indicated that Bacillus spores are more likely to be sustained in soil with a neutral or alkaline pH and a high organic matter content [24,16]. According to Alam, et al. [1], sporulation in *B. anthracis* rapidly occurs when the ambient temperature exceeds 12 °C. In addition to the findings reported by Alam, et al. [1], it was shown that spore generation occurred at temperatures of 10 °C and 7 °C, however, with significantly reduced activity.

The porosity and texture of the soil impact spore retention and penetration, which in turn impacts the transmission to grazing animals [25]. For example, it has been observed that grazing herbivores, including cattle, sheep, and deer, tend to consume spores when they feed on grassy fields that have been infected [26]. Cattle exhibit a higher susceptibility to the disease and have an increased tendency to ingest a significant amount of the bacilli from the soil compared to other herbivores. The difference arises from cattle pulling pasture from the ground, including its roots, whereas other herbivores mostly feed at ground level [1,27]. Winds can spread spores across geographical areas, impacting cattle and human populations far from the initial infection site [28]. Research conducted by Abdrakhmanov, et al. [29] and Kanankege, et al. [30] showed evidence of the role of strong winds in facilitating the dissemination of anthrax spores across extensive areas in Kazakhstan and highlighted the significance of incorporating environmental factors and spatiotemporal analysis into forecasting disease outbreaks. The anthrax outbreak can also be influenced by two important variables: the number of animal host populations and their mobility [31]. Regions characterised by a significant population of hosts exhibit a greater probability of encountering and contracting infectious agents, intensifying the associated risk.

Contacts between humans and animals greatly influence the transmission of anthrax since these interactions provide opportunities for spore exposure via direct contact with infected animals, their byproducts, or contaminated environments [32]. Individuals engaged in livestock management and agricultural and veterinary professionals are more vulnerable to risks and hazards due to their frequent and direct encounters with animals. The research conducted on the anthrax outbreak in Uganda revealed that the occurrence of outbreaks was attributed to the practices of slaughtering and handling carcasses, as well as the absence of regular anthrax vaccinations for cattle [33,34]. Studies on anthrax outbreaks have revealed that those who engage in activities such as the removal of skin from infected carcasses, the handling of meat, and the processing of skins and hides are at an increased risk of contracting the disease, indicating that anthrax presents a higher level of activity in animal carcasses [35]. According to a study conducted by [36], it has been observed that livestock farmers fail to dispose of animals affected with anthrax adequately, hence increasing the risk of potential anthrax infections. Furthermore, the process of urban growth, which involves the interaction of human settlements and domestic animals with wildlife reservoirs, raises the likelihood of disease transmission [37]. The disruption of natural ecosystems caused by deforestation, agricultural expansion, and infrastructural development also can release latent spores.

Examination of Strategies for Anthrax Prevention and Control

The ideas of prevention and control have been derived from the knowledge gained through various incidents and events that have occurred globally.

The spread of anthrax infection can be controlled by early identification and treatment of infected people or animals [38,39]. The anthrax toxin is considered a pathogenic component believed to play a role in infection. The toxin is made up of three polypeptides: Lethal toxin (LT), edema toxin (ET), and protective antigen (PA), known to be individually non-toxic [40,41]. According to Moayeri, et al. (2016) [42], LT and ET share a receptor-binding component and interact with PA to generate two distinct virulent toxins: lethal toxin and edema toxin. Moayeri, et al. [41] proposed that the toxins have significant involvement in two distinct phases of infection, notably the suppression of innate immune response and systemic stage. Hence, a well-established approach for safeguarding against anthrax is routine vaccinations. The vaccines have been developed to target specific virulence components of anthrax to protect against infection [43,44]. According to Coffin, et al. [45], implementing vaccination practices and animal surveillance have been identified as effective measures for reducing the likelihood of anthrax outbreaks.

The study conducted by Fasanella, et al. [46] recommended that isolating affected animals in suspected infection helps reduce the effects of an outbreak. Similarly, appropriate safe disposal of infected carcasses, decontaminating infection sites, and implementing safe land-use practices can effectively control the spread of anthrax spores and contribute to the management of epidemics. Numerous studies have emphasised the importance of appropriate carcass disposal due to the significant risks associated with improper disposition, as seen by the outbreak in Uganda [33]. Providing public education on the risk factors, preventative measures, and proper handling procedures related to animal products is vital, as this can potentially reduce potential risks [45]. A community possessing an extensive understanding is adept at identifying and promptly reporting instances of infection, hence mitigating the impact of an outbreak and providing crucial support to response activities during an outbreak. Education emphasises the acquisition of knowledge and skills about appropriate hygiene techniques, the implementation of safe protocols for handling animals, and the utilisation of protective equipment to eliminate possible risks [47]. In addition, implementing disease surveillance and prediction models allows for adopting preventive measures during the anthrax disease season, reducing its impact [48]. Furthermore, implementing multidisciplinary collaboration among veterinary, public health, and environmental science disciplines might promptly and proactively address anthrax epidemics.

Impact of Anthrax on Public Health in Nigeria

While there are just new incidents of *Anthrax* in Nigeria, its occurrence in other parts of the world has been recorded. Alebie, et al. [49] explained that *Anthrax* is a highly virulent and infectious disease with a significant mortality risk. Animals that eat plants commonly contract anthrax. Infected animals or their products are typically the source of human infection. Individuals involved in handling processed skins, goat hair, and infected wildlife have a heightened susceptibility to anthrax due to their occupational activities.

Additionally, workers at abattoirs, for instance, may contract it through contact with infected meat. By introducing bone meal-containing animal feed, new infection-prone animal regions may emerge. Working in knackeries and handling pet meat can occasionally cause cutaneous rashes. This potential should be considered while evaluating every new case, particularly but not those involving pulmonary anthrax, since this disease may also be used as a weapon in bioterrorism or biowarfare and is most likely to spread by aerosol [49].

In some nations, anthrax epidemics still have a high risk, occasionally affecting people. According to estimates, each anthrax-infected cow in Africa may cause up to ten human cases. However, in wealthy countries, anthrax cases have significantly decreased. In the early 1900s, there were over 130 human cases per year in the US, but today, there are often only one or two cases of cutaneous anthrax per year. Anthrax cases are rare and intermittent in many nations, mostly among veterinarians, agricultural workers, and people who produce items made of hides, hair, wool, and bones. At least 90-95 per cent of all naturally occurring anthrax infections occur on the skin.

With the recent anthrax outbreak in Nigeria, the Nigeria Centre for Disease Control and Prevention (NCDC) activated the incident management system (IMS) at level two. It designated an incident manager to ensure that the reaction was effectively coordinated. With anthrax being endemic in the western part of Africa and earlier cases recorded in Ghana, the likelihood of an outbreak and its possible effects on humans, the risk assessment done by the human health sector has been predicted in Nigeria.

Within 48 hours of receiving information about possible animal deaths, the Federal Ministry of Agriculture and Rural Development (FMARD) was able to identify anthrax and launch an immediate intervention. In order to ensure that any anthrax epidemic in Nigeria is immediately identified, under control, and contained, the Nigerian government has put procedures in place through the FMARD, NCDC, and other one-health stakeholders. As one of these actions, the FMARD established the One-Health Anthrax Technical Working Group to coordinate the national response (Columba & Ifedayo, 2023). NCDC and FMARD both turn on the National Incident Management System. The selection of an incident manager to oversee the human health response. Tracing of contacts among people and animals that came into contact with the index cases.

While the first human case was finally confirmed in July 2023 after several tests and fact-checking, creating an incident action plan (IAP) earlier this year accelerated the public health response. Also, prepositioning medical contraptions and consumables, such as drugs and personal protective equipment (PPEs).

The administration of an anthrax vaccine as a post-exposure prophylactic or pre-exposure preventive strategy is a significant topic within the field of public health. The responses are contingent upon various factors, including the efficacy and safety of extended antibiotic prophylaxis, adherence to antibiotic regimens, the duration until post-exposure antibiotic prophylaxis is initiated, and the attributes of vaccines, such as their effectiveness, safety, and duration required to establish immunity. The Anthrax Vaccine Adsorbed (AVA) vaccine was licensed by the US Food and Drug Administration in 1970 [50].

According to the Centers for Disease Control and Prevention (CDC), individuals exposed to anthrax during the anthrax attacks in the United States in 2001 should be given a 60-day course of antibiotic prophylaxis. Subsequently, patients were recommended to contemplate the possibility of prolonging the antibiotic treatment, with or without administering three doses of the anthrax vaccine. A limited number of individuals adhered to the supplementary guidance, and a minority of patients, specifically fewer than half, complied with the initial 60-day antibiotic treatment plan [2].

Comparison with Global Anthrax Outbreak Trends

Although anthrax is an overlooked disease and whose worldwide distribution is little known, the global variety in anthrax endemism and the intensity of epidemics have previously been characterised [51]. Several studies have used ecological niche models to create regional maps, frequently at the national level, that depict the adaptability of *B. anthracis*. The inclusion of regional mapping activities is an essential component within the broader framework of public health planning [52]. Nevertheless, this research is often conducted in solitary, and the results of these investigations have not yet been consolidated and integrated.

The latest effort to cross-validate regional models reveals either limits in model transferability or significant genetic or ecological variations underpinning distributional patterns of various areas (Mullins, 2013) [53]. In both scenarios, this highlights the constraints that hinder the scalability of regional models to a worldwide estimation. Furthermore, there is a lack of existing models that accurately depict the distribution patterns of anthrax in many significant locations, such as Western Europe, the Middle East, and South America, despite the prevalence of this disease in these areas. Due to the concealed longevity of *Bacillus anthracis* spores in the soil, mapping becomes notably challenging since regions that are endemic and suitable for outbreaks may elapse for periods, ranging from years to even decades, without any recorded instances. The ability to classify into subtypes and determine the geographical origin of the virus is advantageous for epidemiological or forensic investigations related to anthrax [4].

Implications of Anthrax for Public Health Policy

Worldwide, anthrax causes sickness in animal species indigenous to Asia and Africa. Kenya, for instance, reports ten outbreaks on average every year. It had anthrax attack rates of about 15% and 29% in 2014 and 2017, respectively, with 1-5% case fatality rates. Like COVID-19, the fight against anthrax depends on efficient surveillance, containment, and vaccination programmes. Anthrax affects people differently: Cutaneous, gastrointestinal, and inhalational. The most prevalent category is dermal infection from contact with spore-containing animals or animal products. When interacting with sick animals or when an infection has been disseminated through wool or hides, this might happen to veterinarians, agricultural workers, livestock producers, or butchers.

Bacillus anthracis needs a lesion to spread infection and is not invasive. Through skin scrapes or scratches, the spores enter the body and start a local infection that, if left unchecked, could spread to other body parts. When the spores are consumed, the digesting form appears. Tragically, those who lose their animals may also perish while attempting to save anything or eat animal meat. *Bacillus anthracis* continues to pose a significant public health problem and contributes to the devastation caused by SARS-CoV-2 in African communities. However, there is no proof of anthrax being transmitted directly from person to person [54].

The spread of anthrax epidemics varies between regions due to the varying degrees of human-animal interactions and activities in various locations. The influence of weather patterns and differences in the execution of control strategies on outbreaks has been seen, with severe weather events as a major trigger for epidemics [55].

The already overburdened public health systems in Africa are significantly strained by the anthrax epidemic that coincides with the COVID-19 pandemic. In order to lessen the effects on health and the economy, the situation should encourage innovation, teamwork, and increased investment in prevention and containment measures. Due to reporting issues, the number of outbreaks in Africa is unknown, necessitating improving surveillance programmes.

Conclusion

The recent occurrence of anthrax in Nigeria highlights the need for prompt and well-coordinated responses. The Nigerian government has taken proactive measures to address the outbreak, including establishing the One-

Health Anthrax Technical Working Group to coordinate the national response and the implementation of the National Incident Management System. These actions demonstrate a strong commitment to controlling and effectively managing the outbreak. In summary, the anthrax outbreak in Nigeria is an issue of significant concern, both within and globally. The incident is an important reminder of the ongoing risk of zoonotic illnesses. It emphasises the need for comprehensive approaches, including education, vaccination, prompt identification, and collaborative efforts among government agencies. The knowledge gained from this outbreak should encourage adopting a proactive approach to protecting public health against existing and potential infectious disease threats.

Recommendations for Future Outbreaks of Other Infectious Diseases

Preventing animal anthrax reduces the potential danger to humans since cases of naturally occurring human anthrax infections in areas where the illness is prevalent are almost always associated with direct contact with infected animals or their byproducts. The primary method for mitigating animal anthrax is by implementing regular preventative vaccinations. However, in the event of an outbreak, additional control strategies such as quarantine measures, which involve restricting animal movement from affected and surrounding areas, limiting animal contact with anthrax-contaminated environments, and preventing contact between affected and unaffected herds, are also implemented. Globally, administering the *Bacillus anthracis* attenuated Sterne-strain vaccine to domestic animals is common [55]. The co-administration of antibiotics concurrently with vaccination has the potential to considerably decrease the effectiveness of the vaccine due to the live-attenuated nature of the vaccine. It is recommended to provide a revaccination to an animal if it has been exposed to antibiotics for ten days around the time of vaccination. There is uncertainty about the potential impact of simultaneous antibiotic medication on the diminished effectiveness of the vaccination.

Collaboration between public health and animal health entities is essential for detecting anthrax among an animal population to effectively disseminate information to medical and animal health professionals, as well as those residing in regions prone to heightened risk. Exposure reduction may be achieved by circulating information about proper carcass disposal and supplying ranchers with appropriate personal protective equipment. Healthcare practitioners need to consider the administration of antibiotic post-exposure prophylaxis (PEP) in cases when exposure has been detected. Individuals at a heightened risk of exposure, such as veterinary personnel and ranch workers in regions with a high disease prevalence, may find it advantageous to receive an Anthrax Vaccine Adsorbed (AVA). However, it is important to note that this intervention requires a sustained commitment to receiving annual booster doses to maintain adequate protection. In terms of future behaviour modelling, the primary recommendations put forth are the most effective. When developing novel models, it is essential for modellers to thoroughly examine the existing body of psychological research on healthy behaviour and behaviour modification. Furthermore, researchers may use social psychology literature to enhance the intricacy of the social environment shown in infectious disease models, therefore gaining insights into the interconnectedness between human behaviour and the spread of illnesses [56]; in conclusion, it is recommended to include additional context data, such as survey data or observational data, in order to parameterise models with more specificity to the desired behaviour.

Author Declarations

- Ethical Approval: Not required
- Source of funding: None
- Consent: Not applicable
- Acknowledgement: None
- Research registration:

  Name of registry: Not available

  Unique identifying number or registration ID: Not available
- Conflict of Interest: Authors declare no conflicts of interest.
- Guarantor: Tolulope Sharon Rumide
- Competing interest: None.

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