



Sheep anthrax outbreak in Muddaballi Village, Karnataka, India: a comprehensive study of factors

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Summary

Anthrax, caused by *Bacillus anthracis*, remains a persistent threat to global public health and livestock industries. This study investigates a sheep anthrax outbreak in Muddaballi Village, Karnataka, India. Muddaballi has a population of 2,450 people and a livestock population of 2,279 animals, including 756 cows, 82 buffaloes, 1,129 sheep, and 312 goats. The village experienced anthrax outbreaks in 2016, 2021, and 2023, with significant sheep mortalities: 4 out of 200 sheep in 2016, 25 out of 150 sheep in 2021, and multiple incidents in 2023 affecting different farmers with mortality rates ranging from 4 to 20 sheep. The ecological characteristics, including an average annual temperature of 27.0°C and annual rainfall of 587 mm, alongside proximity to the Tungabhadra reservoir, played a crucial role in spore survival and transmission. The study highlights socioeconomic factors and Risk Exposure and Mitigation Behaviour (REMB) as critical determinants of anthrax incidence, with farmers reporting strong agreement on the influence of these factors (Likert scale: 4-5). The integration of AI tools for early detection and rapid response, comprehensive disease surveillance, and ensuring vaccine accessibility are essential measures. Training initiatives for local veterinarians and farmers are also crucial to mitigate future outbreaks. This multifaceted approach is vital for effective anthrax prevention and control in Muddaballi and similar regions.

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Introduction

Anthrax is an acute, infectious, non-contagious, zoonotic disease that remains a threat to public health throughout the world. The causative agent of anthrax is *Bacillus anthracis*, which is a rod-shaped, spore-forming, soil-borne bacterium that survives in the soil under suitable conditions for long periods. *B. anthracis* is an extracellular pathogen that replicates rapidly in the blood, conquering high density to make the host diseased. The soil pH, organic calcium, potassium, and zinc concentrations of soil are believed to be correlated with the survival of spores. Animals come into contact with the spores by grazing grass closer to the surface when the grass is low or scarce or by moving herds to restricted areas when water is scarce (Suresh et al., 2022). The spores are very resistant to unfavourable environmental extremes of heat, cold, desiccation, chemicals and irradiation. The incidence of anthrax varies with the type of soil and climate. It is often restricted to a particular area where it is endemic, and such areas are known as "Anthrax belts". Cattle and sheep are very susceptible to anthrax, and dogs and cats are pretty resistant. There are only a few reports of anthrax outbreaks in domestic animals in India.

Venkatesha et al. (2006) reported two anthrax outbreaks in the Hassan and Kolar districts of Karnataka State.

Material and Methods

Demography, Ecology and Population Dynamics of Muddaballi Village, Koppal Taluk, Koppal District

Muddaballi in Karnataka, India, falls under village location code 601779 and is situated in Koppal taluk of Koppal District. It is positioned 10.2 km away from the District and Sub-district headquarters at Koppal. The total geographical area of the village is 1048.88 hectares with coordinates 5°12'33.4"N Latitude 75°56'12.3"E Longitude (Fig 1.0). Muddaballi has a total population of 2,450 people, out of which the male population is 1,223 while female population is 1,227. The literacy rate of Muddaballi village is 64.90%, out of which 74.65% of males and 55.18% of females are literate. In the town of Muddaballi, the livestock population comprises 756 cows, 82 buffaloes, 1129 sheep, and 312 goats, totalling 2279 animals (Table 2).

Table 1. Demography of Muddaballi Village, Koppal

Area	1048.88 ha
Latitude	5°12'33.4"N
Longitude	75°56'12.3"E
Altitude	526 mt
Population	2,450
Literacy rate	64.90%

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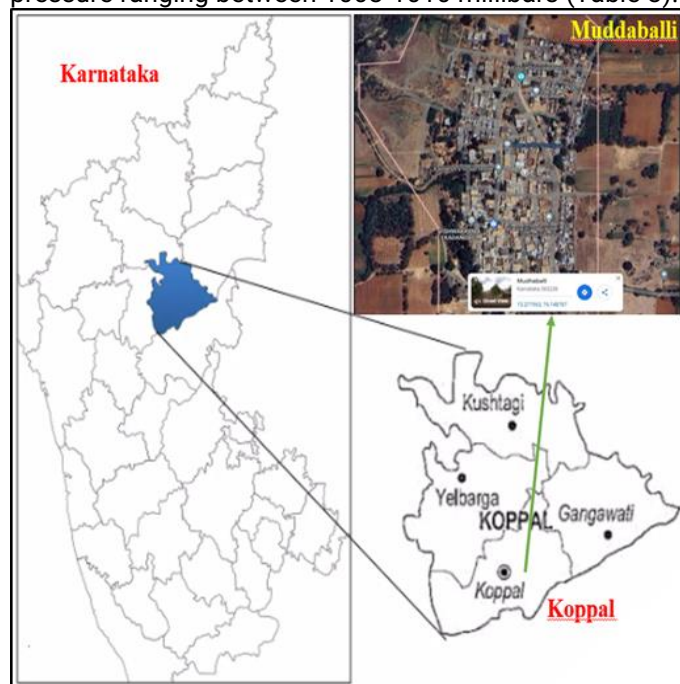
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Table 2. Livestock Population

Cow	Buffalo	Sheep	Goat
756	82	1129	312
Total=2279			

The ecology of Muddaballi village in the Koppal district is characterized by its semi-arid climate, diverse vegetation, wildlife adapted to dry conditions, agricultural practices and the influence of human activities. The Tungabhadra reservoir, situated at Munirabad and bordering Muddaballi village, serves as a primary water resource for nearby towns and also tube wells are primary source of water needs for both agriculture and livestock. The region experiences an average annual temperature of 27.0°C, receives around 587 mm of rainfall annually over 30-40 days, maintains an average annual wind speed of 5.18 meters per second, and sustains an average annual pressure ranging between 1008-1010 millibars (Table 3).

**Figure 1. Google map of Muddaballi Village, Koppal**

The soil type prevalent in the area is primarily composed of Red Loamy soils, which are known for their fertility and suitability for agriculture. Agriculture in this region relies on both rainfed and irrigated methods, with tube wells being a common irrigation source. Major crops cultivated in this region include maize, sugarcane, sorghum, pigeon pea, black gram, green gram, cowpea, and groundnut, reflecting a diverse agricultural landscape that caters to various food and economic needs.

Table 4. Data of Anthrax of Sheep at Muddaballi village

Sl No.	Farmers Name	Total No of Sheep's	No of Sheeps died (Anthrax)	Year in which anthrax occurred/did not occurred	Questionnaire # (Likert Scale: 5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, and 1 = strongly disagree)							
					Socio-economic		REMB		Migration		Preparedness	
					I	II	I	II	I	II	I	II
1.	MH	200	4	2016	5	5	5	5	5	5	5	5
2.	BP	100	20	2023	1	5	5	4	5	4	5	5
3.	MP	150	25	2021	5	4	5	4	5	5	5	5
4.	RP	100	0	2023	5	4	5	5	5	4	5	5

Table 3. Ecological, Soil type and Cropping pattern of Muddaballi village

1.Ave. Temperature	Annual 27.0 °C
2. Ave. Annual Rainfall	587 mm
3.Ave. annual Rainfall days	30-40 days
4.Ave. annual wind speed	5.18mt/sec
5.Ave. annual pressure	1008-1010 MB
6. Soil type	Red Loamy soils
8. Major crops	Maize, sugarcane, sorghum, pigeon pea, black gram, green gram, cowpea, groundnut

Results and Discussions

Risk Factors and Community Responses to Sheep Anthrax in Muddaballi Village

In a survey conducted in Muddaballi village, sheep anthrax cases were recorded among various farmers (Table 4; Figure 2). The analysis of anthrax incidence among sheep farmers revealed varying outbreak years. In 2016, MH had 200 sheep, and 4 of them were infected or died due to anthrax. In 2023, three farmers experienced anthrax issues: BP had 100 sheep with 20 deaths, RP had 100 sheep with no anthrax cases, and GH had 80 sheep with eight deaths. Additionally, BP and KH each had 70 and 100 sheep in 2023, with 4 and 10 deaths, respectively. In 2021, MP had 150 sheep, and 25 of them were affected by anthrax.

The questionnaire responses showed that most farmers strongly agreed on the influence of socio-economic factors in anthrax incidence (Likert Scale: 5). Additionally, farmers generally acknowledged the significance of Risk exposure and mitigation Behaviour (REMB) in anthrax prevention (Likert Scale: 4-5). However, there was variability in responses regarding the relevance of migration patterns (Likert Scale: 1-5). Despite experiencing anthrax outbreaks in different years, their agreement levels vary significantly. While some farmers consistently express strong agreement across all domains, others exhibit mixed responses, suggesting that individual circumstances or experiences with anthrax may influence their perception of risk, preparedness, and migration behaviour. Overall, the data underscores the complexity of farmer attitudes and preparedness in the face of anthrax incidents.

5.	GH	80	8	2023	5	5	5	5	5	5	5	5
6.	BP	70	4	2023	2	4	5	5	5	4	5	5
7.	KH	100	10	2023	2	5	5	5	5	4	5	5

Questionnaire #

Socio-economical: I. Do you think you're hesitant to dispose of anthrax-affected carcasses in a way that goes against your religious teachings? II. Do you think you avoid social gatherings and public spaces due to fears related to the anthrax outbreak?

Risk Exposure and Mitigation Behaviour (REMB): I. Do you think anthrax spores can survive in the soil for extended periods, posing a risk to grazing livestock? II. Do you believe inadequate disease surveillance measures have hindered early detection of anthrax outbreaks?

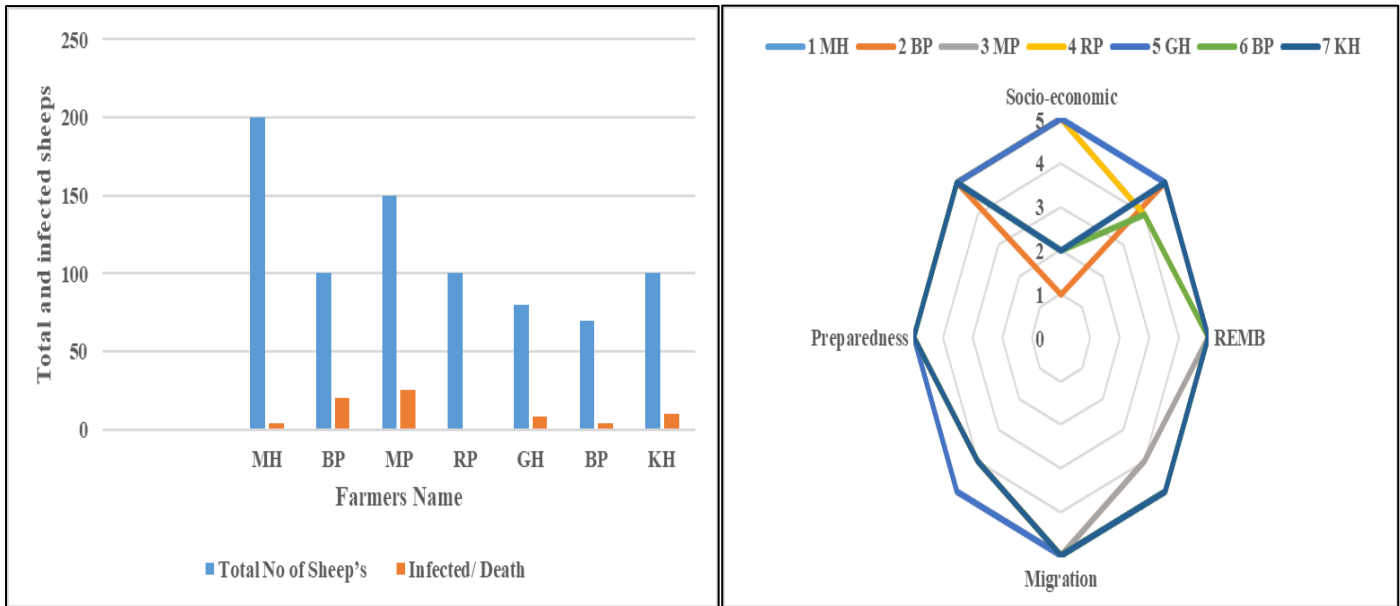
Migration: I. Do you think the unregulated movement of people and livestock can contribute to the spread of anthrax to unaffected areas? II.: Do you think shifting animals or changing grazing areas from infected to uninfected area is effective in avoiding the occurrence of anthrax?

Preparedness: I. Do you think collecting and analysing data helps identify patterns and trends in anthrax cases? II. Do you think prior anthrax outbreak information is essential for preparedness?

Anthrax, an enduring conundrum in numerous regions, presents a significant public health peril owing to its propensity for infecting livestock. In the context of the anthrax outbreak in Muddaballi Village, the persistent challenge arises from the public health risks associated with livestock infections. Field diagnosis relies on clinical indicators, as elucidated by Mongoh (2005); Sushma et al. 2021; Bylaiah et al. 2022; and Indrabalan et al. 2022; emphasising abrupt fatalities and haemorrhaging as key manifestations in affected animals. Anthrax outbreaks

typically originate from spore ingestion in soil, often linked to previous incidents and carcass disposal. The current epidemic in Muddaballi Village reveals two distinct infection categories: the per-acute variant, characterised by sudden fatalities without overt clinical signs, and the acute form, marked by observable symptoms and potential case recovery. Environmental factors, such as bodies of water and the seasonal migration of sheep to the Tungabhadra reservoir influence the dynamics of the outbreak. These elements play a pivotal role in spore transfer, exacerbating the spread of anthrax within the local livestock population.

In Muddaballi Village, where livestock farming and trade are integral to the local economy, there exists a dual challenge of economic sustenance and disease transmission risks within local markets. Insufficient veterinary oversight and adherence to traditional practices further compound these risks. To effectively combat the spread of anthrax through animal marketing, a multifaceted approach is imperative. This includes educational initiatives, implementation of quarantine measures, and collaborative engagement with authorities. The studies conducted by Sushma et al. 2022 and Suresh et al. 2023 underscore the importance of such measures in safeguarding both animal and human health. In conclusion, addressing the anthrax outbreak in Muddaballi Village necessitates a scientific and comprehensive strategy that considers environmental factors, economic dependencies, and the implementation of evidence-based interventions (Sagar et al., 2023a &b; Naveesh et al. 2024). The insights provided by various researchers, as cited in this discussion, contribute to the foundation for effective disease management and prevention in the affected region.



supply of anthrax vaccines, conducting regular training sessions for local veterinarians and farmers, and establishing robust early detection and rapid response mechanisms using Artificial intelligence (AI). Engaging with the community, dispelling myths, and fostering trust is crucial, as is collaborating with international organisations to strengthen disease management efforts. Addressing these aspects holistically is essential for safeguarding the health and livelihoods of both the community and their livestock in Muddaballi Village and similar regions.

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Authors Contribution

The study on the anthrax epidemic in Muddaballi Village, Karnataka, was a collaborative effort led by Suresh K P, who served as the corresponding author and played a pivotal role in designing and executing the research. Sagar N, Jayashree A, Naveesh Y B and Sushma R contributed significantly to data collection and analysis, particularly in gathering vital demographic and ecological information about the village. They also assisted in the study of collected data while providing support in manuscript editing. Suresh K P brought an international perspective, lending expertise in analyzing ecological factors and their influence on the anthrax outbreak. Hemadri D and S S Patil, experts in veterinary epidemiology, contributed to identifying the anthrax-prone area in Koppal and provided brief information regarding the preparation of the questionnaire, in addition to editing the manuscript.

Conflict of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Consent from Farmers

We've recorded videos of each farmer with clear and transparent consent, signifying their willingness to participate in activities involving their land and data, all in adherence to agreements, ensuring transparency and respecting their rights and interests.

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