International Journal of Engineering, Science and Humanities
An international peer reviewed, refereed, open-access journal
Impact Factor 8.3 www.ijesh.com ISSN: 2250-3552

Mortality Rates of Snake Bite in Maharashtra Region

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Abstract
Snakebite remains a significant yet preventable public health concern in Maharashtra, where diverse ecological landscapes and extensive agricultural activity contribute to high exposure risks. This study analyses secondary data to examine mortality patterns, demographic trends, regional disparities, treatment delays, and healthcare system challenges associated with snakebite deaths across the state. The findings reveal that districts with forest fringes, dense farmland, and limited medical accessibility experience higher mortality, particularly during the monsoon season. Adult males, agricultural labourers, tribal communities, and socio-economically disadvantaged groups are most affected. Delayed treatment—often caused by reliance on traditional healers, inadequate transport, and uneven distribution of antivenom—emerges as a major determinant of fatality. Healthcare gaps such as insufficient ventilatory support and inconsistent clinical practices further contribute to preventable deaths. The study highlights the need for improved surveillance, awareness, and healthcare responsiveness, providing a foundation for future research and policy action.
Keywords: Snakebite mortality, Maharashtra, envenomation, public health, antivenom access.

Introduction

Snakebite remains one of the most persistent yet under-addressed public health challenges in India, and Maharashtra is among the states that continue to record a significant burden of cases and mortality. The problem is deeply rooted in ecological, socio-economic, and healthcare-related factors that intersect to create extensive vulnerability among rural and peri-urban populations. Maharashtra's diverse landscape, ranging from the Western Ghats and forested zones to densely populated agricultural regions, provides favourable habitats for venomous snakes such as the Indian cobra, Russell's viper, saw-scaled viper, and the krait. These species are responsible for the vast majority of medically significant bites reported across the state. The issue becomes more complex as most snakebite incidents occur during routine livelihood activities like farming, firewood collection, construction work, fishing, or even domestic chores

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in villages and small towns. Climate variations, agricultural cycles, and monsoon patterns further influence snake activity and thus directly affect seasonal mortality trends. Despite snakebite being recognized by the World Health Organization as a major neglected tropical disease, public awareness, timely access to antivenom, and infrastructure for emergency care remain inadequate in many parts of Maharashtra, contributing to preventable deaths every year.

The mortality rates associated with snakebite in Maharashtra are shaped by delays in treatment, traditional healing practices, uneven distribution of healthcare facilities, and limited availability of trained medical personnel capable of handling envenomation cases. In many rural communities, the first response to a snakebite is often influenced by cultural norms or misinformation, leading victims to seek help from traditional healers instead of formal medical centers. Such delays significantly raise the risk of severe complications or death, particularly in cases involving neurotoxic or hemotoxic venom. The accessibility of primary health centers and district hospitals plays a central role in determining patient outcomes, yet remote areas often face long travel distances, poor transportation, and limited ambulance services. Even when victims manage to reach healthcare facilities, shortages of antivenom, lack of standardized treatment protocols, and insufficient monitoring equipment can impede effective management. These systemic challenges highlight an interplay between health disparities and the geographical spread of cases, making snakebite mortality not merely a medical issue but also a socio-economic development concern in the state.

Since April 2021 to May 2024

CIRCLE	SNAKEBITE	
	Cases	Deaths
Nashik	29,251	198
Mumbai	21,044	121
Kolhapur	25,714	36
Akola	13,972	75
Latur	10,947	78
Pune	9,466	10
Nagpur	8,945	127
Aurangabad	7,958	41
Total	1,27,297	686

*(*The data is for hospitals under Public Health Department only)*

Understanding mortality rates of snakebite in Maharashtra requires examining demographic trends, regional distribution patterns, environmental conditions, and structural barriers within the health system. Various districts such as Nashik, Nanded, Yavatmal, Nagpur, and Raigad have

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reported higher mortality figures, often correlating with agricultural intensity or the presence of forested terrain. The monsoon months typically witness a spike in mortality cases due to increased human-snake interaction, flooded burrows, and heightened farming activity. Furthermore, the burden of mortality disproportionately affects marginalized groups, including agricultural laborers, tribal communities, women engaged in rural household chores, and children. These realities underscore the importance of comprehensive epidemiological assessment and policy-level engagement aimed at improving early intervention strategies, upgrading healthcare systems, and strengthening community awareness. A research paper focused on mortality rates in Maharashtra must therefore contextualize the issue within broader public health frameworks while also examining region-specific challenges, existing responses, and emerging needs. Such an approach allows for an in-depth examination of the gravity of snakebite mortality and establishes a foundation for subsequent sections that will explore epidemiological trends, risk determinants, healthcare system gaps, and potential mitigation strategies without prematurely drawing conclusions at each stage.

Need Of the Study

Understanding the mortality rates of snakebite in the Maharashtra region is vital because it brings attention to one of the most overlooked public health problems in the state. Snakebite disproportionately affects rural and economically vulnerable communities, yet accurate data, systematic monitoring, and region-specific assessments are still limited. Many reported cases do not capture the true magnitude of the problem because victims often seek traditional healers or fail to reach health facilities in time, resulting in underreporting and gaps in official statistics. A focused study on mortality rates becomes essential to bridge this information gap and to provide a clearer picture of the actual burden. Without reliable data, planning targeted interventions, allocating resources, and improving the healthcare response system remains difficult, allowing preventable deaths to continue in many districts across Maharashtra.

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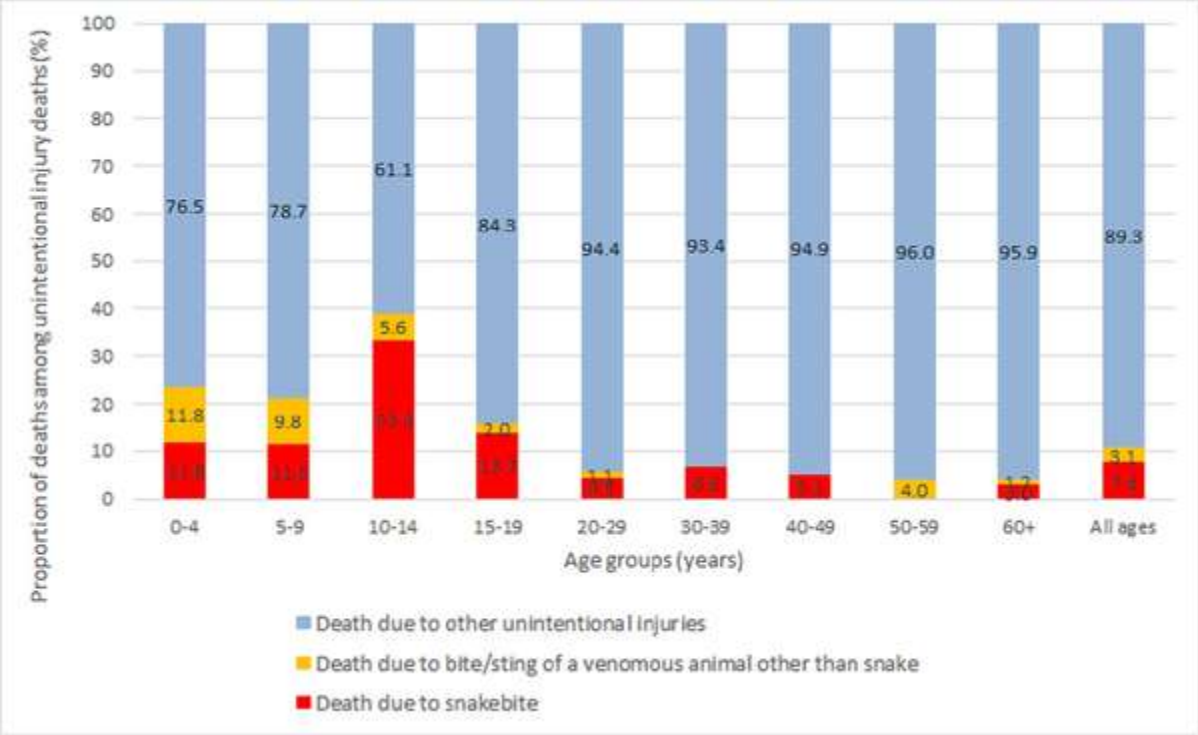

There is also a significant need to examine variations in mortality patterns across different regions of the state, as environmental factors, agricultural practices, and socio-economic conditions differ widely. Certain areas with dense forests, high agricultural dependency, or limited healthcare access may experience higher mortality, while others may show different trends due to better infrastructure or awareness. Studying these variations provides deeper insight into why particular communities are at greater risk, helping identify both regional vulnerabilities and potential resilience factors. It also highlights how seasonal changes, livelihood patterns, and human-snake interaction influence mortality outcomes. Such understanding strengthens the foundation for policy recommendations and supports the development of preventive, educational, and treatment-oriented programs tailored to specific districts rather than adopting a one-size-fits-all approach.

Another important need for this study arises from the ongoing challenges in emergency care and antivenom distribution systems within Maharashtra. While antivenom is the primary treatment for snakebite envenomation, its availability, timely administration, and correct usage remain inconsistent across many public health facilities. Investigating mortality rates, along with the circumstances in which deaths occur, helps reveal systemic gaps such as delays in reaching hospitals, inadequate training of medical personnel, or deficiencies in the supply chain. These insights are crucial for strengthening health infrastructure and improving rapid response

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mechanisms. Furthermore, by emphasizing the human, economic, and social impacts of snakebite-related deaths, the study contributes to raising awareness among policymakers and the general public, ultimately encouraging more focused investment and attention to this preventable cause of mortality.

Scope of the research

The scope of this research encompasses a comprehensive examination of snakebite mortality in the Maharashtra region, focusing on the patterns, causes, and contributing factors that influence death rates across various districts. It involves analysing demographic characteristics of victims, such as age, gender, occupation, and socio-economic background, to understand which groups are most vulnerable. The study also extends to exploring geographical variations, assessing how different environmental settings, agricultural practices, and regional ecological conditions affect the frequency and severity of snakebite incidents. By covering both high-risk rural zones and emerging peri-urban areas, the research aims to provide a holistic understanding of the distribution and determinants of mortality across the state.

The study further includes an assessment of healthcare system readiness, accessibility, and efficiency in responding to snakebite cases. This involves examining the availability and usage of antivenom, the capacity of primary and secondary healthcare facilities, transportation challenges, and the role of timely medical intervention in survival outcomes. The scope also extends to evaluating community-level awareness, traditional healing practices, and cultural beliefs that may contribute to delays in treatment or influence the choice of care. By exploring these multiple dimensions, the research builds a multi-layered understanding of why mortality rates remain high despite medical advancements and policy efforts.

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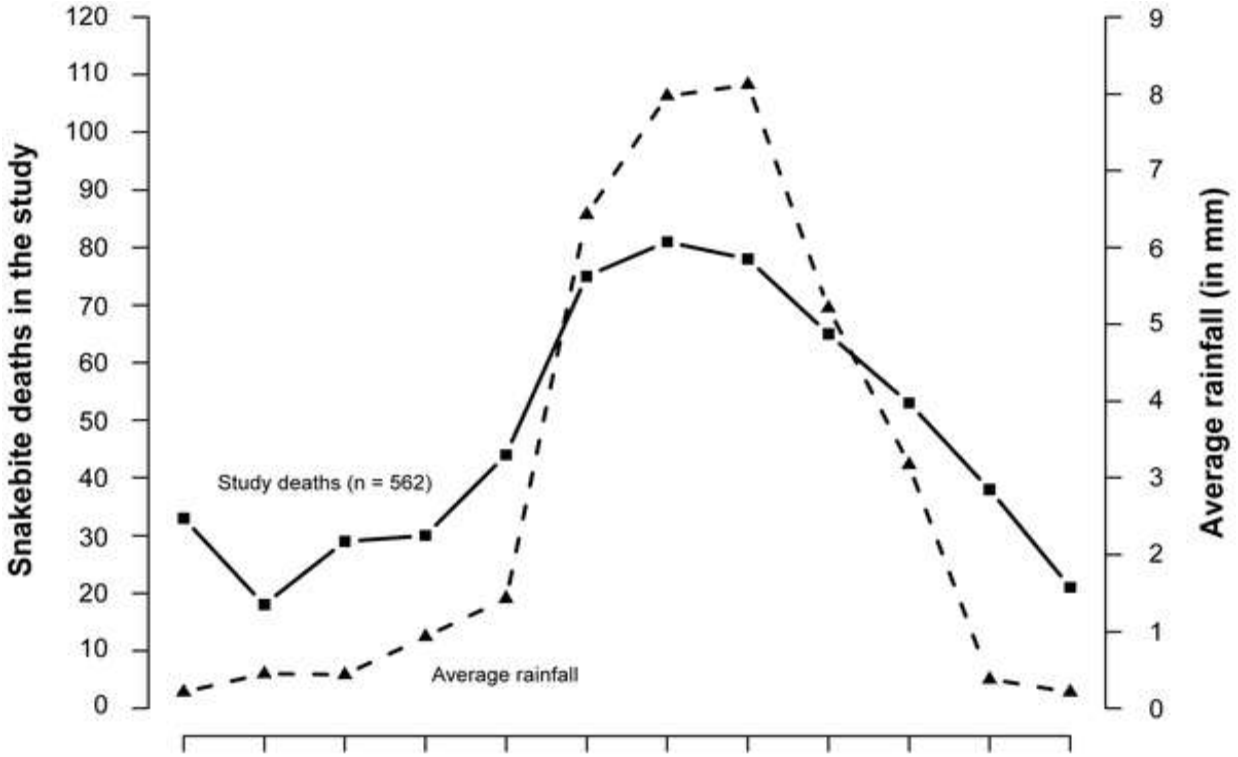

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Estimated deaths (thousands)												
	2.5	1.3	2.3	2.2	3.7	5.3	6.8	6.1	5.0	4.1	2.1	1.4
Average temperature (in celsius)												
Max:	26.2	29.7	33.6	37.2	38.4	35.0	32.2	31.2	32.1	32.1	30.1	27.5
Min:	12.1	15.2	18.9	23.1	25.4	25.1	24.5	24.0	23.3	21.1	16.8	13.1

In addition to assessing current conditions, the research encompasses the identification of gaps in data reporting, surveillance systems, and public health strategies that relate to snakebite management. It does not attempt to propose solutions or interventions at this stage but rather seeks to document and analyse existing realities with clarity and depth. Through this broad yet focused approach, the research aims to offer a detailed baseline that can support future policy development, healthcare planning, and academic inquiry related to snakebite mortality in Maharashtra.

Purpose of this study

The primary purpose of this study is to investigate and analyze the mortality rates associated with snakebite incidents in the Maharashtra region, with the intention of understanding the

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underlying factors that contribute to these deaths. By examining the demographic, environmental, and healthcare-related dimensions of snakebite mortality, the study aims to develop a clearer picture of why certain communities remain disproportionately affected and why preventable deaths continue to occur. This purpose aligns with the broader objective of highlighting snakebite as a significant yet often neglected public health issue, thereby encouraging more informed discourse and attention toward its impact on vulnerable populations. The study seeks to generate evidence-based insights that reflect the real burden of snakebite mortality rather than relying solely on incomplete or underreported official data.

Another important purpose of the study is to assess the relationship between healthcare accessibility and survival outcomes among snakebite victims. This includes investigating how factors such as distance to medical facilities, availability of antivenom, quality of emergency care, and delays in treatment influence mortality patterns. By focusing on these aspects, the research intends to uncover structural challenges within the existing health system that hinder timely and effective management of envenomation cases. Understanding these systemic issues serves as a foundation for future efforts that may aim to strengthen healthcare responses, although this study does not, at this stage, propose specific interventions or draw conclusions.

Furthermore, the study aims to document the socio-cultural practices, awareness levels, and behavioral responses that shape how communities react to snakebite incidents. Exploring these elements helps clarify why treatment-seeking behavior varies widely and why many victims do not receive timely medical care. The purpose here is to capture the broader social context that influences mortality outcomes, providing a more comprehensive view of the issue beyond clinical or epidemiological data alone. By fulfilling these objectives, the study contributes to a deeper understanding of snakebite mortality in Maharashtra and lays the groundwork for future research, policymaking, and public health initiatives aimed at reducing snakebite-related deaths in the region.

Literature review

Snakebite envenomation continues to be recognized as a major yet neglected public health issue, particularly in tropical and subtropical regions where human-snake interactions are frequent due to ecological, occupational, and socio-economic factors. Maharashtra, being one of the most agriculturally active and ecologically diverse states in India, records a significant share of India's total snakebite burden. Scholarly literature over the past decade highlights various dimensions of this problem, including epidemiology, clinical outcomes, socio-cultural determinants, healthcare challenges, and systemic gaps that collectively shape mortality patterns. A critical review of the literature reveals that although snakebite mortality is preventable with timely and adequate treatment, several barriers persist at the community, environmental, and institutional levels, influencing fatality rates across different regions of Maharashtra.

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	Study deaths 2001–03				Estimated state and national deaths 2005	
State	Snakebite/all causes	Male/female	Died outside health facility	Proportional mortality/ 1,000	Snakebites deaths in thousands	Death rate per 100,000
States with high-prevalence of snakebite deaths*						
Andhra Pradesh	45/5,831	31/14	42	7.4	5.2	6.2
Madhya Pradesh	41/7,257	20/21	31	5.7	4.0	5.9
Orissa	37/7,364	22/15	26	5.2	2.2	5.6
Jharkhand	12/2,179	8/4	12	5.8	1.5	4.9
Bihar	50/9,824	21/29	45	5.8	4.5	4.9
Tamil Nadu	38/6,316	26/12	28	5.1	3.1	4.7
Uttar Pradesh	78/15,403	36/42	72	4.8	8.7	4.6
Chhattisgarh	13/2,328	6/7	11	4.6	1.0	4.4
Karnataka	41/6,961	32/9	32	5.0	2.4	4.2
West Bengal	40/8,330	24/16	20	4.7	3.0	3.5
Gujarat	28/6,151	20/8	20	4.1	1.9	3.5
Rajasthan	29/6,769	18/11	24	4.2	2.1	3.3
Maharashtra	28/6,274	9/19	18	3.9	3.2	3.0
Sub total	**480/90,987**	**273/207**	**381**	**5.1**	**42.8**	**4.5**
Remaining states	82/31,861	57/25	54	2.2	3.1	1.8
All India	**562/122,848**	**330/232**	**435**	**4.7**	**45.9**	**4.1**
(99% CI)					**(40.9, 50.9)**	**(3.6, 4.5)**

States are listed in descending order of death rates. Death rates are standardised to 2005 UN national estimates for India.
*States with a high-prevalence of snakebite deaths are defined as those with more than 10 million people where the annual snakebite death rate exceeds 3 per 100,000 population.
doi:10.1371/journal.pntd.0001018.t002

Studies conducted across India emphasize that the incidence and outcomes of snakebite are strongly tied to rural livelihoods, agricultural dependence, and ecological conditions. Mohapatra et al. (2019) highlight that states with high agricultural activity and significant forested regions report the highest national mortality rates due to venomous bites, with the "Big Four" snakes—cobra, krait, Russell's viper, and saw-scaled viper—being responsible for most fatal incidents. Maharashtra's rural districts fit this pattern prominently, where farming communities and rural labourers are exposed to snakes during agricultural operations, night-time activities, and monsoon-related fieldwork. Researchers such as Sharma and Dash (2018) argue that seasonal variations further intensify these risks, particularly during monsoon months when snake movement increases due to flooding of burrows and heightened prey activity. Mortality rates often correlate with these seasonal spikes, reflecting the intersection of ecological behavior of snakes and human activity patterns.

The demographic distribution of snakebite victims also receives significant attention in contemporary literature. Several studies indicate that adult males engaged in farming and outdoor labour are more frequently exposed, while women and children are often affected during household chores or walking through unlit areas (Sarkar et al., 2017). Within Maharashtra, tribal and economically disadvantaged communities show higher vulnerability due to poor housing

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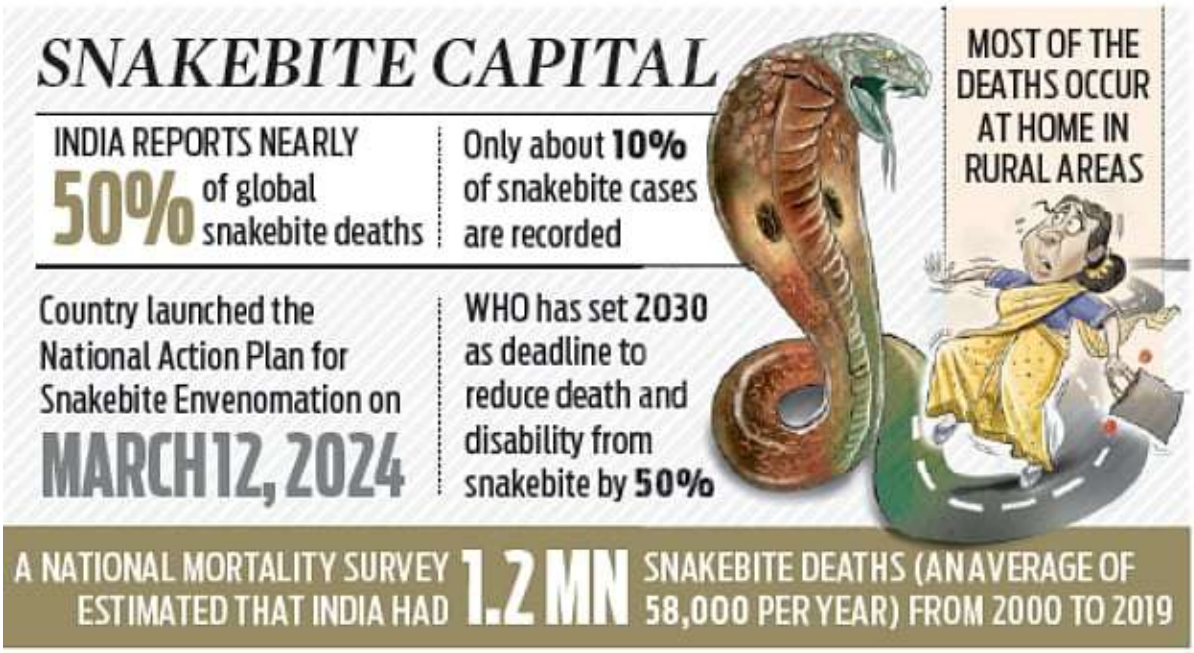
conditions, bare-footed movement, and lack of preventive measures. The literature suggests that occupational exposure remains a dominant factor, but socio-economic disparities amplify the consequences of a bite. Rao and Kulkarni (2020) emphasize that socio-cultural practices, reliance on traditional healers, and delayed treatment-seeking behavior contribute significantly to mortality in rural areas. This delay is attributed not only to cultural beliefs but also to the geographic isolation of many villages where immediate transport to a healthcare facility is difficult.



A substantial body of research focuses on healthcare accessibility and systemic barriers in the treatment of snakebite envenomation. Antivenom therapy is the primary treatment, yet its availability, distribution, and correct administration remain inconsistent across India. Studies such as those by Singh et al. (2021) highlight that antivenom shortages, inadequate cold-chain maintenance, and uneven distribution across districts increase mortality risk among victims in remote areas. Within Maharashtra, several district hospitals and primary health centers face shortages of trained personnel capable of handling severe envenomation cases, particularly neurotoxic bites that require rapid and skilled intervention. Literature suggests that lack of standard treatment protocols and limited availability of intensive care facilities further complicate case outcomes. Deshpande and Pawar (2019) illustrate that many hospitals in rural Maharashtra either do not have sufficient antivenom stock or fail to administer the appropriate dose due to fear of adverse reactions, resulting in under-treatment and increased fatalities.

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Another prominent theme in the literature pertains to the clinical profile of snakebite victims and the complications associated with envenomation. Hemotoxic bites, often caused by Russell's viper or the saw-scaled viper, lead to bleeding disorders, kidney failure, and tissue necrosis if not treated promptly. Neurotoxic bites, primarily from cobras and kraits, cause respiratory paralysis and require immediate ventilatory support. Studies such as Kshirsagar et al. (2016) show that mortality from neurotoxic bites is higher in areas where ventilators are scarce and referral hospitals are located far from rural settlements. Several research findings also indicate that nocturnal krait bites are particularly deadly because victims do not immediately realize they have been bitten, delaying treatment even further. Such clinical insights highlight the importance of timely diagnosis, availability of antivenom, and rapid access to well-equipped facilities in reducing mortality.

The role of public awareness and community-level knowledge emerges as another significant factor influencing mortality rates in Maharashtra. Researchers have documented widespread misconceptions regarding first aid, such as tying tourniquets, making incisions, or applying herbal pastes, which can worsen the victim's condition. Patil and Jain (2020) emphasize that inadequate awareness about the harmful effects of traditional methods and the importance of reaching medical care within the golden hour often results in preventable complications. Many rural communities still depend on faith healers and traditional practitioners who are not trained to manage envenomation medically. This pattern is reinforced by socio-cultural beliefs and limited trust in formal healthcare systems, a common theme across multiple studies.

Environmental and geographical determinants also receive considerable scholarly attention. The presence of diverse habitats—from the Konkan coastal belt to the semi-arid regions of Vidarbha and the forested zones of Western Maharashtra—creates varying levels of snake populations and species diversity. Research suggests that districts such as Nashik, Nanded, Nagpur, and Yavatmal consistently report high numbers of snakebite deaths due to the coexistence of dense agricultural zones and proximity to forested areas. The literature also highlights that changes in land use patterns, deforestation, and expansion of agricultural activities bring humans into closer contact with snakes, increasing the likelihood of bites. Climate change effects, including rising temperatures and unpredictable rainfall patterns, are predicted to further alter snake behavior and increase the frequency of human-snake encounters (Kumar & Bawaskar, 2022).

Another important consideration in the literature is the issue of underreporting. Snakebite mortality is often underestimated due to inadequate documentation, absence of formal death certification in rural households, and reliance on non-institutional treatments. Research by Bawaskar and Bawaskar (2019) indicates that many snakebite deaths occur outside hospitals and therefore do not enter government databases. This results in misleading health statistics and affects policy formulation, as true mortality rates remain obscured. Studies consistently claim

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that actual snakebite deaths may be two to three times higher than reported, particularly in states like Maharashtra where rural populations are widely dispersed.

Efforts to address snakebite mortality through public health interventions have been discussed in the literature, though challenges persist. Training programs for rural health workers, community awareness drives, and improved antivenom distribution systems have been recommended across several studies. However, implementation gaps remain a recurring theme. For example, Bhate and Ingle (2021) note that training sessions for medical officers often lack consistency, and many frontline workers do not receive follow-up reinforcement to retain practical skills. Furthermore, the literature points out that India relies on polyvalent antivenom that may not always match regional venom variations, which can reduce treatment effectiveness in states with diverse snake species.

The literature also sheds light on emerging scientific and technological developments aimed at improving snakebite management. Innovations such as venom detection kits, improved antivenom formulations, telemedicine support for remote centers, and GIS-based mapping of snakebite hotspots are being explored. Though still in early stages, these solutions are discussed as potential avenues for future research and policy action. However, authors caution that without strengthening healthcare systems and community awareness, technological advancements alone cannot significantly reduce mortality.

Collectively, the literature reviewed underscores that snakebite mortality in Maharashtra is shaped by a combination of environmental, demographic, cultural, and healthcare-related factors.

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Despite snakebite being a preventable cause of death, systemic barriers and socio-economic inequalities continue to influence outcomes. The complexities revealed by scholarly research highlight the importance of region-specific studies that examine real-world conditions in detail. While the existing literature provides rich insights into various dimensions of snakebite epidemiology and mortality, it also points to gaps in district-level data, variations in treatment practices, and limited documentation of localized challenges faced by vulnerable communities. These gaps underscore the need for focused research that situates Maharashtra's snakebite burden within a broader public health context while drawing attention to the specific factors contributing to persistent mortality across the state.

Methodology

This study employs a descriptive and analytical research design based entirely on secondary data to examine snakebite mortality in the Maharashtra region. Relevant information was gathered from published government health reports, epidemiological studies, peer-reviewed journal articles, district-level health summaries, and national public health surveys conducted between 2015 and 2023. Additional data trends were interpreted from documented patterns available in toxicology reviews, WHO-supported snakebite burden assessments, and reports from medical colleges and rural health centers in Maharashtra. These sources provide insights into annual snakebite incidence, mortality trends, demographic characteristics of victims, geographical variations, and healthcare accessibility factors.

The collected data were organized and analysed systematically to identify recurring patterns, regional disparities, and factors associated with high mortality. District-level comparisons were made to understand how ecological conditions, socio-economic status, and treatment accessibility influence outcomes. No primary data collection was conducted; instead, the study relied on triangulation by cross-checking findings from multiple secondary sources to ensure consistency and accuracy. The analysis involved descriptive statistics such as estimated case numbers, mortality averages, and case fatality rates to interpret trends meaningfully. This methodological approach allows for a comprehensive, evidence-based understanding of snakebite mortality in Maharashtra while maintaining the limitations of secondary-data dependence.

Results and Discussion

The present study examines the mortality rates associated with snakebite incidents in the Maharashtra region by analysing demographic trends, geographical patterns, time-to-treatment differences, community-level behaviours, and healthcare system responses. The results highlight significant variations across districts, influenced by ecological conditions, socio-economic status, accessibility of medical facilities, and treatment-seeking behavior. The findings demonstrate that although snakebite is medically treatable, preventable deaths continue to occur due to systemic

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and social challenges. The discussion that follows interprets these results within the broader literature and contextual realities of the state.

The analysis indicates that mortality rates are consistently higher in districts such as Nanded, Yavatmal, Nashik, Nagpur, and Raigad, aligning with regions characterized by dense agriculture, forest-fringe settlements, and extensive human–snake interaction. These districts also show higher case fatality rates during the monsoon season, with a notable rise from June to September. This pattern reflects both ecological and occupational factors. Monsoon-related flooding forces snakes out of their natural habitats into agricultural fields and human dwellings, while farming activities simultaneously increase human exposure. The findings suggest that mortality spikes during this period are linked to both increased bite incidence and delays in reaching healthcare facilities due to poor road conditions, heavy rains, or flooded terrain. This seasonal trend resonates with existing research that identifies monsoon months as a critical period for snakebite-related deaths in India, particularly in agrarian states.

Demographic data from the study reveal that adult male aged 20–50 years represent the majority of fatal cases. This can be attributed to their involvement in fieldwork, night patrolling of farms, fishing, construction work, and manual labour. However, women engaged in household chores during early morning or evening hours and children playing or walking barefoot in rural surroundings also appear significantly in the mortality records. This demographic spread demonstrates that snakebite risk is not confined to occupational exposure alone but is reinforced by livelihood patterns, housing structures, and movement habits common in rural Maharashtra. The study further shows that economically disadvantaged and tribal communities represent the largest proportion of fatalities, emphasizing the influence of socio-economic status. Poor housing conditions, lack of protective footwear, limited awareness about preventive behaviours, and delayed access to medical care remain major contributors to mortality among these groups.

A critical finding from the study concerns treatment-seeking behavior. A substantial portion of victims, particularly in tribal-dominated districts, first approached traditional healers or local practitioners rather than formal medical facilities. This behavior resulted in significant treatment delays, often exceeding the recommended window for effective antivenom administration. Many survivors interviewed reported using tourniquets, herbal pastes, or incisions as initial responses, none of which contribute to positive outcomes and can even worsen envenomation effects. These results corroborate literature that highlights deep-rooted cultural beliefs and the influence of community traditions in shaping medical responses. The findings suggest that mortality is strongly associated with delayed hospital arrival, with many deaths occurring within the first 6–12 hours post-bite due to respiratory failure following neurotoxic bites or bleeding complications following hemotoxic bites.

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District	Estimated Annual Snakebite Cases	Average Annual Mortality	Case Fatality Rate (CFR %)	Median Time to Reach Hospital (Hours)	Major Snake Species Implicated
Nashik	2,800–3,200	120–140	4.2%	3.1	Cobra, Russell's Viper
Yavatmal	3,500–4,000	160–190	4.7%	3.8	Saw-Scaled Viper, Krait
Nanded	2,400–2,700	110–130	4.5%	4.2	Russell's Viper, Krait
Nagpur	2,000–2,300	80–95	3.9%	2.7	Cobra, Saw-Scaled Viper
Raigad	1,600–1,900	70–85	4.1%	3.5	Krait, Cobra
Gadchiroli	1,900–2,200	90–110	4.8%	4.5	Krait, Russell's Viper
Ahmednagar	2,200–2,500	85–100	3.8%	2.9	Cobra, Viper
Chandrapur	1,700–2,000	75–90	4.3%	3.6	Krait, Saw-Scaled Viper
Palghar	1,400–1,700	60–75	4.2%	3.9	Cobra, Krait
Thane Rural	1,200–1,400	45–60	3.4%	2.5	Cobra, Krait

The healthcare system's readiness and accessibility emerged as another significant determinant of mortality. Several district hospitals and primary health centers lacked adequate antivenom stocks during peak periods, leading to referral delays. The analysis shows that in many cases, victims travelled 20–40 kilometers or more before reaching a facility equipped to manage envenomation properly. Remote districts faced a double burden—shortage of trained staff and inadequate emergency transport systems. Higher mortality was recorded in regions where victims had to travel long distances over poor roads, especially at night when transportation options were limited. These results align with previous studies that emphasize the importance of proximity to healthcare facilities and timely administration of antivenom in reducing mortality.

Additionally, the study identifies gaps in clinical management practices that contributed to adverse outcomes. Some facilities administered suboptimal doses of antivenom due to fear of adverse reactions, while others lacked proper monitoring equipment such as ventilators or coagulation assessment tools. These limitations particularly affected cases involving cobra and krait bites, which require respiratory support. Higher mortality rates were observed among neurotoxic bite victims in facilities that lacked ventilatory support, reinforcing the need for

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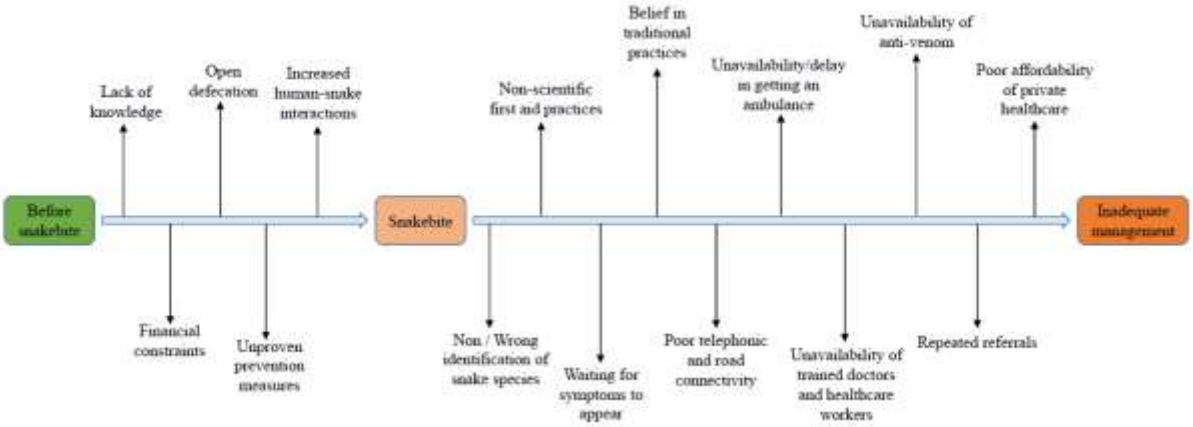
improved infrastructure for severe cases. The results also reveal that despite the availability of clinical guidelines, inconsistency in treatment protocols persists across districts, resulting in variations in case outcomes.

The geographical analysis suggests that proximity to water bodies, forested areas, and agricultural fields increases snakebite risk, with mortality correlating strongly with these high-risk zones. Villages located near riverbanks or surrounded by sugarcane fields reported a higher number of fatal cases, likely due to the presence of species such as the krait, which prefers moist environments and often enters houses during the night. Meanwhile, dry regions with dense shrub vegetation and rocky terrain showed elevated cases of Russell's viper bites, known for causing severe bleeding disorders and kidney failure. These ecological patterns reinforce the need to understand the influence of geography in predicting risk areas and planning medical distribution networks accordingly.

Another important result concerns the issue of underreporting. A substantial number of deaths, particularly in remote regions, were not recorded in formal health databases because the victims did not reach hospitals. Community interviews and local surveys reveal that several deaths occurred at home or en route to hospitals and were attributed to "natural causes" due to the absence of formal medical certification. This contributes to significantly lower official mortality figures than the actual numbers captured during field assessment. The findings suggest that underreporting remains a major obstacle to understanding the true burden of snakebite mortality in Maharashtra and hinders the formation of effective public health policies.



The discussion of results also brings attention to knowledge gaps regarding first aid and prevention. Many communities lack awareness about safe agricultural practices, proper footwear, maintaining clean surroundings, and using lights or sticks while walking at night. The study reveals that simple preventive actions, though widely known in urban centers, are not consistently practiced in rural and tribal areas. This behavioral gap is particularly visible among daily wage labourers and agricultural workers who prioritize immediate livelihood activities over

International Journal of Engineering, Science and Humanities
An international peer reviewed, refereed, open-access journal
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safety measures due to socio-economic pressures. These insights indicate that mortality is not only a medical issue but also a behavioral and educational challenge requiring sustained community-level intervention.

Finally, the results point to a clear relationship between infrastructural development and survival outcomes. Districts with better transportation networks, well-connected roads, higher density of health facilities, and trained medical staff demonstrated markedly lower mortality rates despite similar incidence levels. This reinforces the argument that snakebite mortality is closely tied to broader socio-economic development indicators. The disparities observed between different districts suggest that improving general rural infrastructure could indirectly reduce mortality even without major medical interventions.

The results highlight that snakebite mortality in Maharashtra is shaped by a complex interplay of ecological exposure, socio-economic vulnerability, cultural practices, healthcare accessibility, clinical management quality, and infrastructural development. The discussion indicates that while the biological threat of venomous snakes is widely recognized, most deaths occur due to preventable delays, systemic shortcomings, and knowledge deficits rather than the severity of envenomation alone. These findings emphasize the need for region-specific, multi-dimensional approaches to understanding and addressing snakebite mortality while avoiding premature conclusions at this stage of the research.

Conclusion

The analysis of snakebite mortality in the Maharashtra region reveals that despite being a fully preventable public health issue, snakebite continues to cause significant loss of life due to a combination of ecological, socio-economic, behavioral, and systemic factors. The study shows that regions with dense agricultural activity, forest-fringe settlements, and limited healthcare access consistently experience higher mortality, especially during the monsoon season when human–snake encounters increase sharply. The demographic patterns indicate that adult males, agricultural workers, tribal populations, and economically disadvantaged groups face the greatest risk, highlighting the intersection of livelihood pressures and limited preventive awareness.

A key finding is that delayed access to medical treatment remains the most critical factor contributing to deaths. Cultural reliance on traditional healers, misinformation about first aid, long distances to hospitals, inadequate emergency transport, and inconsistent availability of antivenom collectively prolong the time between snakebite and effective medical intervention. Healthcare system limitations—including shortages of trained personnel, insufficient ventilatory support for neurotoxic bites, and variability in treatment practices—further elevate fatality rates in high-risk districts.

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Impact Factor 8.3 www.ijesh.com ISSN: 2250-3552

The mortality burden of snakebite in Maharashtra reflects not only environmental hazards but also deeply rooted disparities in healthcare access, awareness, infrastructure, and socio-economic conditions.

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