



One Health for Public Health Security in India and the Indian Himalayan Region: Epidemiological, Ecological and Health-System Perspectives

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Abstract

Background: Human health is closely linked to the health of animals, plants and ecosystems. Land-use change, biodiversity loss, climate variability, antimicrobial use, urbanisation and increasing movement of people and animals can alter exposure pathways and influence the emergence or distribution of health risks. These interactions are particularly relevant to India, where diverse ecological settings coexist with large and mobile human and animal populations.

Methods: A structured narrative review was undertaken using peer-reviewed literature and authoritative policy and technical documents from international agencies and Indian government sources. Literature was organised thematically around the foundations of One Health, zoonotic spillover, antimicrobial resistance, climate-sensitive disease, the Indian Himalayan Region, surveillance, governance and workforce development.

Results: The reviewed evidence supports an integrated approach to surveillance and prevention across human, animal and environmental sectors. Environmental change can modify contact between wildlife, livestock and people; antimicrobial residues and resistance determinants can circulate across human, animal and environmental settings; and climatic conditions can influence vector ecology and the geographic and seasonal distribution of some infectious diseases. The Indian Himalayan Region presents additional challenges because of ecological sensitivity, changing land use, tourism, livestock-based livelihoods, difficult terrain and variable access to health and veterinary services. India's National One Health Mission provides an institutional platform for cross-sectoral coordination. Community Medicine can contribute through epidemiological surveillance, outbreak investigation, risk communication, operational research, community engagement and intersectoral coordination. Competency-based One Health education should be incorporated into existing undergraduate, postgraduate and field epidemiology training rather than treated solely as a separate subject.

Conclusion: One Health is a practical framework for strengthening prevention, preparedness and response when it is translated into locally relevant surveillance, governance, workforce development and community participation. For Himalayan states, implementation should be evidence-informed and adapted to district-level ecological, epidemiological and health-system contexts.

Keywords: One Health; Zoonoses; Antimicrobial Resistance; Climate Change; Surveillance; Community Medicine; Indian Himalayan Region; Public Health Security

Introduction

Health risks increasingly arise from interactions among people, animals and the environment. Emerging infectious diseases provide a clear example. Analysis of global emerging infectious disease events has shown that zoonotic pathogens account for a substantial proportion of events and that many zoonotic events have a wildlife origin [1]. Such findings do not imply that every environmental disturbance causes disease emergence; rather, they indicate that ecological and socioeconomic conditions can influence opportunities for pathogen exposure and transmission.

Outbreaks of SARS, Nipah virus disease, Ebola virus disease, highly pathogenic avian influenza and COVID-19 have highlighted the importance of considering human–animal–environment interfaces alongside conventional clinical and epidemiological surveillance. Land-use change, agricultural expansion, wildlife–livestock contact, population movement and changes in vector ecology may alter the pathways through which pathogens reach human populations. At the same time, antimicrobial resistance (AMR) illustrates how health risks can move across hospitals, farms, food systems and environmental compartments.

One Health provides a framework for addressing these interconnected risks through collaboration among human health, animal health, environmental and other relevant sectors [2–4]. The Quadripartite One Health Joint Plan of Action identifies six action areas, including strengthening One Health capacities, addressing zoonotic and vector-borne diseases, food safety, AMR and environmental health [2]. In India, the National One Health Mission has been established as a cross-ministerial initiative to coordinate and integrate One Health activities and strengthen preparedness and disease control [5].

This review examines the epidemiological and ecological basis of One Health, with particular attention to India and the Indian Himalayan Region. It also considers how Community Medicine can contribute to surveillance, prevention, education and intersectoral coordination. The objective is not to present One Health as a replacement for existing public-health programmes, but to identify practical areas in which existing systems can be better connected.

Review approach and methods

This manuscript is a structured narrative review. It was designed to synthesise conceptual, epidemiological, ecological,

policy and educational literature relevant to One Health rather than to calculate a pooled quantitative effect estimate. A narrative approach was selected because the evidence base includes heterogeneous study designs, outbreak reports, ecological studies, surveillance literature, policy documents and workforce-development frameworks.

Literature identification was guided by the concepts of One Health, zoonotic spillover, emerging infectious diseases, AMR, climate-sensitive disease, vector ecology, biodiversity, land-use change, cross-sectoral surveillance, the Indian Himalayan Region and One Health education. Peer-reviewed literature and authoritative documents from WHO, FAO, UNEP, WOA and Government of India sources were prioritised. Reference lists of key publications were also examined for directly relevant material.

Sources were retained when they addressed one or more of the following themes: conceptual foundations of One Health; ecological drivers of disease emergence; AMR; climate and vector ecology; Indian and Himalayan public-health contexts; governance and surveillance; and workforce development. Evidence specific to the Himalayan region was treated cautiously where district-level data were limited. Findings were synthesised narratively. No formal risk-of-bias assessment or meta-analysis was undertaken, and the review is therefore not presented as a systematic review.

One Health as a systems approach

One Health can be understood as an integrated approach in which the health of people, animals, plants and ecosystems is considered together. Its practical value lies in identifying interactions that may be missed when surveillance, research and policy are organised entirely within separate sectors [2–4]. The approach is especially relevant to problems for which exposures or determinants cross sectoral boundaries, including zoonoses, AMR, food safety and some climate-sensitive diseases.

From an epidemiological perspective, risk can be considered at several interconnected levels. At the individual level, susceptibility and behaviour influence exposure and disease. At the population level, density, mobility and immunity affect transmission. At the ecosystem level, land use, biodiversity, climate and vector habitats can modify exposure opportunities. Governance, socioeconomic conditions and access to services influence both vulnerability and the capacity to respond.

One Health therefore complements rather than replaces conventional epidemiology. It extends the field of enquiry upstream, encouraging public-health teams to consider where pathogens and resistance determinants originate, how exposure occurs, and which sectors can contribute to prevention before illness becomes widespread.

Ecological and social drivers of emerging infections

Zoonotic emergence and land-use change

Zoonotic pathogens account for a substantial share of documented emerging infectious disease events [1]. Environmental change can increase opportunities for contact among wildlife, domestic animals and people. Habitat fragmentation, agricultural expansion, livestock production and settlement near wildlife habitats may create new interfaces, although the relationship is context-specific and should not be interpreted as a simple causal chain.

The emergence of Nipah virus disease in Malaysia illustrates the importance of such interfaces. Fruit bats served as the natural reservoir, while changes in agricultural and livestock systems contributed to opportunities for transmission to pigs and subsequently to people [1,6]. The example demonstrates why outbreak prevention may require attention not only to clinical surveillance but also to animal production practices, wildlife ecology and environmental change.

Biodiversity and the dilution-effect hypothesis

The relationship between biodiversity and infectious disease risk is complex. The dilution-effect hypothesis proposes that higher host diversity may reduce transmission of some pathogens by altering the abundance or encounter rate of highly competent hosts. However, this effect is not universal and depends on pathogen, host, vector and ecosystem characteristics. Consequently, biodiversity conservation should not be presented as a stand-alone disease-control intervention; rather, ecological integrity is one component of a broader set of determinants that can influence disease risk.

Urbanisation and environmental health

Rapid urbanisation can concentrate populations, increase human-animal contact at urban margins and place pressure on water, sanitation and waste-management systems. Standing water, poorly managed waste and inadequate drainage can support

mosquito breeding, while environmental contamination can increase the risk of waterborne and other infections. These risks are strongly influenced by local infrastructure and governance and therefore require locally tailored interventions.

Zoonotic spillover and prevention

Spillover can be viewed as a sequence of events rather than a single occurrence. A pathogen must be present in a reservoir, an exposure pathway must bring it into contact with a susceptible host, infection must be biologically possible, and onward transmission must be sustained for an outbreak to expand.

This framework identifies several opportunities for prevention: reducing unnecessary high-risk contact; improving occupational protection for farmers, animal handlers, veterinarians and other exposed groups; strengthening animal and wildlife surveillance; improving laboratory detection; and ensuring rapid investigation of unusual disease signals. One Health surveillance aims to connect these signals so that action can occur earlier in the chain.

Antimicrobial resistance as a one health problem

AMR is influenced by antimicrobial exposure and the movement of resistant organisms and resistance genes across human, animal and environmental settings [7]. Human healthcare remains a major setting for stewardship and infection prevention, but antimicrobial use in animals, food production and other sectors can also exert selection pressure. Antimicrobial residues and resistant organisms may enter wastewater, soil and surface-water systems, creating opportunities for persistence and transmission.

An effective One Health response therefore combines antimicrobial stewardship, infection prevention and control, laboratory surveillance, appropriate veterinary prescribing, regulation of antimicrobial use, and improved management of pharmaceutical and healthcare waste. Integrated surveillance is particularly valuable because resistance patterns observed in one sector may have relevance to another.

Climate change and infectious disease ecology

Climate affects infectious disease risk through changes in temperature, rainfall, humidity, extreme events and ecological conditions. Vector-borne diseases are particularly sensitive because climatic conditions influence vector survival, reproduction, biting behaviour and pathogen development [8]. Climate change

can therefore alter the timing, intensity or geographic suitability of transmission, although the direction and magnitude of change vary by pathogen, vector, geography and public-health conditions.

Modelling studies also indicate that climate and land-use change can alter opportunities for viral sharing among wildlife species, providing a plausible pathway through which environmental change may influence zoonotic risk [9]. These findings should be interpreted as risk projections rather than predictions of specific outbreaks.

For public health, the practical implication is the need to combine routine disease surveillance with relevant meteorological, ecological and vector information. Such integration can support early warning, targeted vector control and preparedness, particularly when interpreted alongside local surveillance data.

The Indian Himalayan Region: public-health implications

The Indian Himalayan Region contains diverse ecosystems, dispersed settlements and substantial climatic and geographic variation. Health services in many mountain areas must also operate across difficult terrain and seasonal changes in accessibility. These characteristics make the region relevant to One Health planning, while also requiring caution against treating the entire Himalaya as a single epidemiological unit.

Environmental and climate-related change

Changes in temperature and precipitation can affect water availability, agriculture and vector ecology. Evidence from Himachal Pradesh supports the importance of local surveillance: dengue has been documented in Kangra, with a 2017–2022 secondary-data analysis reporting 441 laboratory-positive cases among 6008 suspected cases tested, with a seasonal pattern from late August to November [18]. An outbreak investigation in Bilaspur in 2018 also documented *Aedes aegypti* and *Aedes albopictus* breeding in affected areas [16].

These observations establish local disease and vector activity but should not be interpreted as proof that climate change caused their distribution or temporal pattern.

Tourism and population mobility

Tourism and seasonal population movement are important features of Himachal Pradesh and other Himalayan states.

Temporary increases in population density can place additional demands on water, sanitation, waste management and health services. From a One Health perspective, preparedness at major tourist and pilgrimage sites should therefore include routine surveillance, food and water safety, waste management and mechanisms for rapid communication between local health authorities and other relevant agencies.

Human–wildlife and livestock interfaces

Road development, agricultural activity, tourism and changing land-use patterns can modify interactions between people, livestock and wildlife. Livestock-based livelihoods and seasonal movement of animals may also create repeated opportunities for exposure. These interfaces warrant surveillance and risk assessment, but specific pathogen risks should be established through local epidemiological, veterinary and ecological evidence rather than assumed from geographic proximity alone.

Vector surveillance

Changes in vector distribution are an important area for Himalayan public-health research. Recent primary studies demonstrate that vector surveillance in Himachal Pradesh is feasible and epidemiologically relevant. In Kangra district, longitudinal and cross-sectional surveys documented seasonal bionomics of *Anopheles* mosquitoes and examined associations with climatic variables [15]. An entomological investigation during a 2018 dengue outbreak in Bilaspur district identified *Aedes aegypti* and *Aedes albopictus* and reported high larval indices in affected areas [16]. In addition, molecular detection of *Leishmania donovani* in *Phlebotomus longiductus* collected from villages in Shimla, Kullu and Kinnaur districts provides evidence of an established sand-fly–*Leishmania* interface in parts of the Sutlej valley [17]. These findings support continued integrated entomological and human-disease surveillance, but they do not by themselves demonstrate climate-driven altitudinal expansion of transmission.

Role of community medicine in operationalising one health

Community Medicine has a practical role in translating One Health principles into population-level action. The discipline brings together epidemiology, surveillance, prevention, health education, programme evaluation and community engagement, all of which are relevant to integrated health-risk management.

Surveillance and outbreak investigation

Medical colleges and public-health institutions can contribute to integrated surveillance by linking human disease information with relevant veterinary, environmental and ecological observations. Community Medicine teams can support outbreak investigation, descriptive epidemiology, risk assessment, field surveys and evaluation of surveillance systems.

Community participation and risk communication

Farmers, pastoralists, forest workers, animal handlers and local communities can provide early information about unusual animal illness, wildlife mortality or changes in vector abundance. Participatory approaches should be designed so that reporting is accessible, feedback is provided and communities are not stigmatised or penalised for reporting events. Risk communication should clearly distinguish confirmed information from uncertainty.

Intersectoral coordination

Implementation requires functional communication among health, animal husbandry, wildlife, forestry, agriculture, environment, water and sanitation and disaster-management authorities. Community Medicine professionals can contribute as facilitators of joint planning, surveillance review, outbreak investigation and training, while recognising that leadership and accountability must remain shared across sectors.

One Health education and workforce development

One Health competencies are increasingly being defined in terms of observable knowledge, skills and professional behaviours rather than simply adding another topic to an already crowded curriculum. Earlier competency work identified domains including management, communication and informatics, ethics, leadership, teamwork, roles and responsibilities, and systems thinking [10]. The WHO–FAO–WOAH COHFE framework subsequently defined 14 domains for One Health field epidemiology, covering technical and functional competencies across different training levels [11].

Domain	Expected capability	Suggested learning activity	Assessment
Systems thinking	Relate human, animal and ecosystem determinants of health	Concept mapping; case-based discussion	Structured case analysis
Surveillance and epidemiology	Interpret human, animal and environmental signals	Outbreak simulation; field exercise	Practical/OSPE-style exercise
Environmental health	Identify ecological and climate-related determinants	Field visit; GIS/environmental assessment	Field report
AMR and stewardship	Recognise cross-sector resistance pathways and apply stewardship principles	Audit; multidisciplinary seminar	Project/viva
Risk communication	Communicate uncertainty and engage communities without stigma	Role play; community exercise	Observed structured exercise
Interprofessional collaboration	Define roles and work effectively across disciplines	Joint workshops/case conferences	Team-based assessment
Leadership and ethics	Address accountability, data sharing and ethical trade-offs	Policy simulation; reflective learning	Portfolio/reflection
Research	Formulate feasible One Health research questions	Journal club; operational research	Project/dissertation evaluation

Table 1: Suggested competency-based integration of One Health into medical and public-health education.

For MBBS education, One Health can be integrated into existing teaching through case-based learning, outbreak exercises, field visits and discussions of zoonoses, AMR, environmental health and climate-sensitive diseases. At postgraduate level, Community Medicine training can incorporate intersectoral outbreak investigation, surveillance evaluation, operational research, risk communication and data interpretation. Where feasible, joint learning with veterinary and environmental disciplines can strengthen understanding of roles and responsibilities.

Governance priorities for India

India has an institutional basis for strengthening One Health through the National One Health Mission, which brings together multiple ministries and agencies and is intended to coordinate existing activities and address gaps [5]. Further implementation should focus on practical interoperability rather than simply creating additional structures.

First, human, animal and relevant environmental surveillance systems should have defined mechanisms for data sharing, joint signal verification and coordinated response. Second, workforce development should include competencies for multidisciplinary surveillance, field investigation, communication and leadership. Third, medical colleges, veterinary institutions, environmental agencies and research organisations should be encouraged to develop place-specific research networks. Fourth, climate and ecological information should be used where it demonstrably improves disease surveillance and preparedness. Fifth, AMR control should extend beyond clinical stewardship to veterinary use, food systems, wastewater and environmental management.

Emerging technologies and future directions

Metagenomic sequencing, environmental DNA, remote sensing, geographic information systems and artificial intelligence may strengthen One Health surveillance. These tools can improve pathogen detection, environmental monitoring, spatial risk assessment and anomaly detection when appropriate data and technical capacity are available.

However, technology should be considered an enabling component rather than a substitute for surveillance personnel, laboratories, governance or community trust. An early-warning signal is useful only when there is a defined pathway for verification,

decision-making and response. Future One Health programmes should therefore evaluate technologies according to their public-health utility, feasibility, cost, data-quality requirements and capacity to improve decisions.

Limitations

This review has limitations inherent to its narrative design. It does not provide a systematic, reproducible quantitative synthesis or formal risk-of-bias assessment. The breadth of the topic required integration of evidence from different study designs and policy sources. Evidence relating specifically to the Indian Himalayan Region is uneven, particularly for local human-wildlife contact patterns, vector distribution and climate-disease relationships. Accordingly, several Himalayan observations are presented as areas for surveillance and research rather than as established causal relationships. Implementation of One Health also varies across Indian states and institutions; the recommendations should therefore be adapted to local epidemiology, governance and available resources.

Conclusion

One Health provides a practical framework for addressing health risks that cross human, animal and environmental boundaries. The evidence reviewed here supports greater integration of surveillance, preparedness, AMR stewardship, environmental health and workforce development, while recognising that the strength of evidence differs across settings and diseases.

For India, the National One Health Mission provides an important institutional platform for this work. In the Indian Himalayan Region, implementation should be based on district-level surveillance and ecological evidence and should account for terrain, population mobility, livestock practices, environmental change and health-system capacity. Community Medicine can contribute through epidemiological intelligence, field investigation, community engagement, health education, operational research and intersectoral coordination.

The most useful measure of progress will not be the number of One Health committees or documents created, but whether information from different sectors is converted into earlier detection, better prevention and more coordinated action.

Embedding One Health competencies within existing medical and public-health education can help develop a workforce capable of supporting this approach.

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Ethical Approval

Not applicable because this manuscript is a narrative review of published and policy literature.

Author Contribution

The author conceived the review, synthesised the literature and prepared the manuscript.

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