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Veterinary extension and public health: Strategies for zoonotic disease prevention and community safety

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Abstract

Zoonotic diseases constitute a significant proportion of emerging infectious diseases and pose major challenges to global health systems, food security, and socio-economic stability. Veterinary extension plays a vital role in bridging the gap between scientific knowledge and community practices by promoting awareness, improving animal health management, and facilitating disease prevention strategies. This article examines the role of veterinary extension within the framework of veterinary public health, emphasizing integrated approaches such as surveillance, vaccination, biosecurity, and the One Health concept. It further discusses epidemiological trends, community-based interventions, and policy frameworks aimed at reducing zoonotic risks. The study highlights challenges in implementation, particularly in developing regions, and proposes future strategies for strengthening community safety through interdisciplinary collaboration and technological innovation.

Keywords: Zoonotic diseases, veterinary extension, veterinary public health, one health approach, disease surveillance, vaccination strategies, biosecurity measures, community awareness, epidemiology, disease control, environmental health

Introduction

Zoonotic diseases, defined as infections naturally transmitted between vertebrate animals and humans, have gained increasing global attention due to their critical role in recent public health emergencies and pandemics, reflecting their complex epidemiological nature and far-reaching consequences across human, animal, and environmental health systems (WHO *et al.*, 2021) [36]. Zoonoses account for nearly 60 percent of all known infectious diseases and approximately 75 percent of emerging pathogens, highlighting their significant contribution to global disease burden and the urgent need for integrated prevention strategies (FAO *et al.*, 2022) [10]. Rapid urbanization has intensified human-animal interactions by expanding settlements into wildlife habitats, thereby increasing the risk of pathogen spillover events and facilitating the emergence of novel infectious diseases (Jones *et al.*, 2019) [15]. Environmental degradation, including deforestation, biodiversity loss, and ecosystem disruption, further exacerbates zoonotic risks by altering natural host-pathogen dynamics and promoting closer contact between humans and disease reservoirs (Keesing *et al.*, 2018) [16]. Climate change has also emerged as a major driver of zoonotic disease transmission by influencing vector distribution, pathogen survival, and host migration patterns, thereby reshaping disease epidemiology on a global scale (Carlson *et al.*, 2022) [6]. Intensified livestock production systems, driven by increasing demand for animal-based food products, contribute to disease emergence through high-density animal populations, poor biosecurity practices, and increased opportunities for pathogen amplification and transmission (Grace *et al.*, 2017) [13]. Globalization and increased trade and travel have further accelerated the spread of zoonotic diseases across borders, complicating disease control efforts and necessitating coordinated international responses (Tatem *et al.*, 2018) [31]. The interconnected nature of these determinants is best understood through the One Health framework, which emphasizes the integration of human, animal, and environmental health to address complex health challenges in a holistic and collaborative manner (Zinsstag *et al.*, 2020) [40]. This framework recognizes

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that the health of people is closely linked to the health of animals and the environment, and it promotes interdisciplinary collaboration among veterinarians, physicians, ecologists, and policymakers to develop effective disease prevention and control strategies (Destoumieux-Garzón *et al.*, 2018) ^[9]. Within this context, the conceptual representation of One Health, as illustrated in Figure 1, demonstrates the interdependence of these domains and highlights the need for coordinated interventions at multiple levels to reduce zoonotic risks and improve public health outcomes (Rabinowitz *et al.*, 2018). The increasing frequency and severity of zoonotic outbreaks underscore the limitations of traditional sectoral approaches and reinforce the importance of integrated frameworks that address the root causes of disease emergence rather than focusing solely on reactive measures (Bonilla-Aldana *et al.*, 2020) ^[5]. Veterinary extension emerges as a critical component of this integrated approach by serving as a bridge between scientific knowledge and community practices, facilitating the dissemination of information, technologies, and best practices to farmers, livestock owners, and other stakeholders (Singh *et al.*, 2022) ^[30]. Through education, training, and participatory approaches, veterinary extension enhances community awareness of zoonotic risks and promotes behavioral changes that contribute to disease prevention and control (Kumar *et al.*, 2021) ^[19]. It also plays a vital role in strengthening local capacity for disease surveillance and response by empowering

communities to recognize early signs of disease and adopt appropriate preventive measures (Thumbi *et al.*, 2019) ^[32]. In addition, veterinary extension supports the implementation of vaccination programs, biosecurity measures, and improved animal husbandry practices, thereby reducing the risk of disease transmission at the animal-human interface (Havelaar *et al.*, 2020) ^[14]. The role of veterinary extension is particularly important in low- and middle-income countries, where limited access to veterinary services and public health infrastructure poses significant challenges to effective disease control (Bardosh *et al.*, 2022) ^[3]. By fostering collaboration between government agencies, research institutions, and local communities, veterinary extension contributes to the development of sustainable and context-specific solutions for zoonotic disease prevention (Narrod *et al.*, 2020) ^[24]. Furthermore, the integration of digital technologies, such as mobile applications and data-sharing platforms, has enhanced the effectiveness of extension services by improving communication, data collection, and real-time monitoring of disease outbreaks (McArthur *et al.*, 2021) ^[21]. The growing burden of zoonotic diseases necessitates coordinated efforts across disciplines and sectors, emphasizing the importance of adopting a One Health approach supported by strong veterinary extension systems to translate knowledge into practice and enhance community resilience against emerging health threats (Mulenga *et al.*, 2022) ^[23].

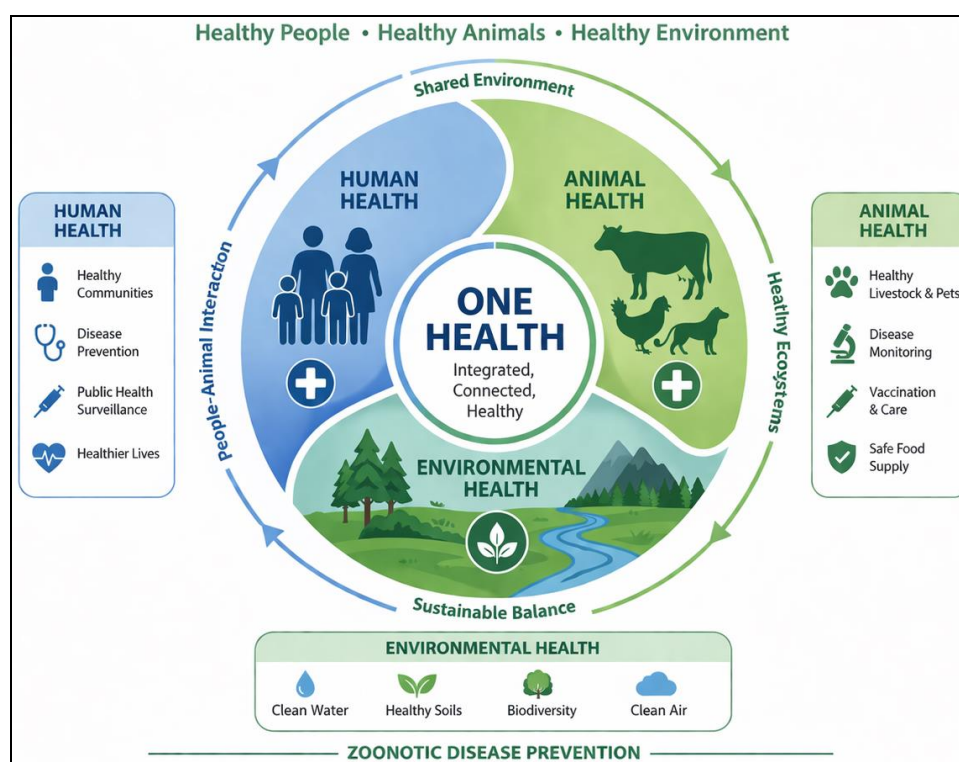


Fig 1: Conceptual representation of the One Health framework showing the integration of human, animal, and environmental health in zoonotic disease prevention

Veterinary Extension: Concept and Scope

Veterinary extension refers to the systematic dissemination of veterinary knowledge, technologies, and practices to farmers, livestock owners, and rural communities with the aim of improving animal health, productivity, and public health outcomes through informed decision-making and behavioral change (Open Access Pub *et al.*, 2024). It encompasses structured educational interventions that include training programs, farmer field schools, awareness campaigns,

advisory services, and participatory learning approaches designed to enhance knowledge and skills among livestock stakeholders (Frontiers *et al.*, 2025) ^[17]. Veterinary extension operates as a critical interface between research institutions and field-level implementation, ensuring that scientific innovations are effectively translated into practical applications within diverse agro-ecological and socio-economic contexts (Penn State Extension *et al.*, 2024). The functional framework of veterinary extension integrates

knowledge transfer, stakeholder engagement, and behavioral change mechanisms, enabling the adoption of improved animal husbandry practices and disease prevention strategies (Huang *et al.*, 2026). By facilitating continuous learning and adaptive management, veterinary extension contributes to strengthening livestock systems and improving resilience against emerging animal health challenges (Makarabbi *et al.*, 2025). One of the primary objectives of veterinary extension is to promote preventive healthcare practices, including vaccination, deworming, biosecurity, and hygiene management, thereby reducing the incidence of infectious and zoonotic diseases (Frontiers Research Topic *et al.*, 2025) [17]. Extension programs also emphasize the importance of early disease detection and reporting, which enhances surveillance systems and supports timely intervention to control disease outbreaks (Research in Veterinary Science *et al.*, 2025). Through participatory approaches, veterinary extension encourages active involvement of farmers in decision-making processes, leading to improved adoption of recommended practices and sustainable livestock management (Ritter *et al.*, 2018). The effectiveness of veterinary extension is influenced by various socio-economic factors such as education level, gender roles, herd size, and access to resources, which determine the extent to which farmers adopt new technologies and practices (Roche *et al.*, 2018). Gender-inclusive extension strategies have been recognized as essential for improving livestock productivity and ensuring equitable access to veterinary services, particularly in rural communities where women play a significant role in animal husbandry (Sumner *et al.*, 2018). Veterinary extension also plays a vital role in enhancing food safety by promoting hygienic production practices and reducing the risk of contamination in animal-derived products (Havelaar *et al.*, 2020) [14]. In addition, it supports antimicrobial stewardship by educating farmers on the rational use of veterinary drugs, thereby addressing the

growing threat of antimicrobial resistance (McArthur *et al.*, 2021) [21]. The integration of digital technologies, such as mobile-based advisory systems and data-driven decision-support tools, has further strengthened veterinary extension services by improving communication, accessibility, and real-time monitoring of animal health (Zhou *et al.*, 2025) [39]. These innovations enable extension workers to deliver timely and context-specific information to farmers, enhancing the effectiveness of extension programs and improving disease management outcomes (Liang *et al.*, 2026) [20]. Furthermore, veterinary extension contributes to environmental sustainability by promoting practices that minimize the ecological impact of livestock production, such as waste management, efficient resource utilization, and climate-resilient farming systems (Kock *et al.*, 2020). The role of veterinary extension in zoonotic disease prevention is particularly significant, as it facilitates awareness about transmission risks, encourages safe handling of animals, and promotes preventive measures that protect both human and animal health (Bonilla-Aldana *et al.*, 2020) [5]. In developing countries, where access to veterinary services is often limited, extension systems serve as a crucial mechanism for delivering essential animal health services and improving rural livelihoods (Bardosh *et al.*, 2022) [3]. By fostering collaboration among government agencies, research institutions, and local communities, veterinary extension enhances the effectiveness of public health interventions and contributes to the achievement of broader development goals (Narrod *et al.*, 2020) [24]. Ultimately, veterinary extension represents a dynamic and evolving field that integrates education, communication, and innovation to address complex challenges in animal health and public health, ensuring sustainable livestock development and improved community well-being (Zinsstag *et al.*, 2020) [40].



Fig 2: Functional framework of veterinary extension services illustrating knowledge transfer, stakeholder engagement, and community-level implementation

Epidemiology of Zoonotic Diseases

The epidemiology of zoonotic diseases involves complex and dynamic interactions among hosts, pathogens, and

environmental factors that collectively influence disease occurrence, transmission patterns, and outbreak potential across different geographical regions and populations (Jones

et al., 2019)^[15]. These interactions are further shaped by socio-economic conditions, ecological transformations, and human behavioral practices that determine exposure risk and vulnerability to infection (Allen *et al.*, 2017). Changes in land use, deforestation, and biodiversity loss have significantly altered natural ecosystems, increasing contact between wildlife, livestock, and humans, thereby facilitating the spillover of zoonotic pathogens (Keesing *et al.*, 2018)^[16]. Climate change also plays a critical role in modifying disease epidemiology by affecting vector distribution, pathogen survival, and seasonal transmission patterns, leading to the emergence and re-emergence of zoonotic diseases in new regions (Carlson *et al.*, 2022)^[6]. Rapid urbanization and population growth have intensified human-animal interactions, particularly in peri-urban areas, where inadequate sanitation and overcrowding create favorable conditions for disease transmission (Hassell *et al.*, 2017). Globalization, including increased trade and travel, has further accelerated the spread of zoonotic diseases across borders, complicating containment efforts and necessitating coordinated international responses (Tatem *et al.*, 2018)^[31]. Transmission pathways of zoonotic diseases are diverse and include direct contact with infected animals, indirect exposure through contaminated environments, and vector-borne transmission via insects such as mosquitoes and ticks, all of which are conceptually illustrated in Figure 3 to provide a comprehensive understanding of disease dynamics (Plowright *et al.*, 2017). Direct transmission occurs through bites, scratches, or handling of infected animals, while indirect transmission involves contact with contaminated water, soil, or food products, highlighting the importance of hygiene and sanitation in disease prevention (Havelaar *et al.*, 2020)^[14]. Vector-borne transmission is particularly significant in tropical and subtropical regions, where climatic conditions support the proliferation of vectors and increase the risk of diseases such as dengue, malaria, and Rift Valley fever (Rocklöv and Dubrow, 2020).

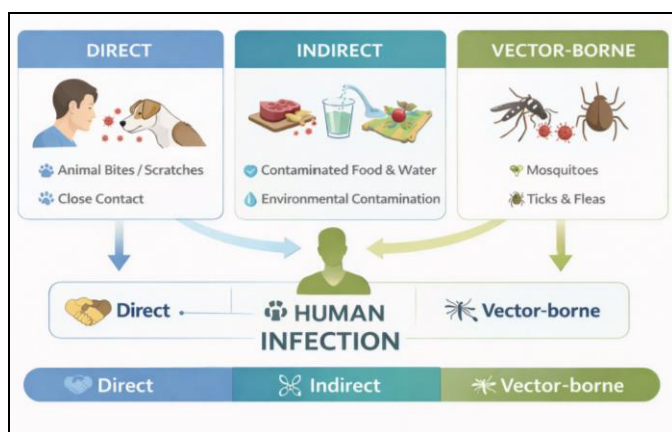


Fig 3: Major transmission pathways of zoonotic diseases including direct, indirect, and vector-borne routes

The epidemiological patterns of zoonotic diseases are also influenced by host factors such as immunity, genetics, and population density, which determine susceptibility and transmission dynamics within communities (Gibb *et al.*, 2020)^[12]. Pathogen characteristics, including virulence, mutation rate, and adaptability, further contribute to disease emergence and persistence, making surveillance and monitoring essential for early detection and control (Woolhouse *et al.*, 2018)^[34]. In addition, socio-cultural practices such as consumption of raw animal products,

traditional farming methods, and close proximity to livestock increase the risk of zoonotic infections, particularly in rural and resource-limited settings (Grace *et al.*, 2017)^[13]. Major zoonotic diseases, including rabies, avian influenza, brucellosis, and leptospirosis, represent significant public health concerns due to their high morbidity and mortality rates, and their reservoirs and transmission routes are systematically summarized in Table 1 within this section to provide clarity on epidemiological patterns and associated risk factors (WHO *et al.*, 2021)^[36]. Rabies, primarily transmitted through dog bites, remains a leading cause of zoonotic mortality in many developing countries, while avian influenza spreads through contact with infected poultry and contaminated environments (FAO *et al.*, 2022)^[10]. Brucellosis is commonly transmitted through direct contact with infected livestock or consumption of unpasteurized dairy products, whereas leptospirosis is associated with exposure to water contaminated with urine from infected rodents and other animals (CDC *et al.*, 2023)^[7]. Table 1, which presents these diseases along with their reservoirs and modes of transmission, serves as a valuable reference for identifying priority areas for intervention, surveillance, and targeted public health strategies (Zinsstag *et al.*, 2020)^[40]. Effective epidemiological understanding of zoonotic diseases is essential for designing evidence-based prevention and control measures, including vaccination programs, vector control strategies, and community awareness initiatives (Bonilla-Aldana *et al.*, 2020)^[5]. Integrated surveillance systems that combine human and animal health data play a crucial role in detecting outbreaks early and implementing timely interventions to reduce disease spread (Mulenga *et al.*, 2022)^[23]. Furthermore, the application of advanced technologies such as geographic information systems, remote sensing, and predictive modeling has enhanced the ability to monitor disease trends and identify high-risk areas, thereby improving preparedness and response strategies (Carlson *et al.*, 2022)^[6]. The growing complexity of zoonotic disease epidemiology underscores the need for interdisciplinary collaboration and the adoption of a One Health approach that integrates human, animal, and environmental health perspectives to address emerging challenges effectively (Destoumieux-Garzón *et al.*, 2018)^[9].

Table 1: Major zoonotic diseases with their animal reservoirs and transmission routes

Disease	Animal Reservoir	Mode of Transmission
Rabies	Dogs, wild carnivores	Animal bites, saliva exposure
Avian Influenza	Poultry, wild birds	Contact with infected birds, aerosols
Brucellosis	Cattle, goats, sheep	Direct contact, unpasteurized dairy products
Leptospirosis	Rodents, livestock	Contaminated water, urine exposure
Tuberculosis	Cattle	Aerosol inhalation, raw milk consumption
Anthrax	Livestock	Contact with spores, contaminated soil

Veterinary Public Health and Its Role

Veterinary public health is a multidisciplinary field that focuses on protecting human health through the control of animal diseases, ensuring food safety, and managing environmental risks, thereby forming a critical component of global health systems and disease prevention strategies (WHO *et al.*, 2021)^[36]. It integrates knowledge from veterinary science, epidemiology, environmental health, and public

health to address complex health challenges arising at the human-animal-environment interface (FAO *et al.*, 2022) ^[10]. One of the primary objectives of veterinary public health is to prevent zoonotic diseases by targeting the animal source of infection, thereby reducing transmission risks before pathogens reach human populations (CDC *et al.*, 2023) ^[7]. This preventive approach is essential because controlling diseases at their origin is more effective and sustainable than managing outbreaks after human infection occurs (Zinsstag *et al.*, 2020) ^[40]. The discipline also emphasizes food safety by ensuring that animal-derived products are free from contaminants and pathogens, thereby protecting consumers and maintaining public confidence in food systems (Havelaar *et al.*, 2020) ^[14]. Environmental risk management is another critical aspect, as ecological factors such as water quality, waste disposal, and climate conditions significantly influence disease transmission dynamics (Carlson *et al.*, 2022) ^[6]. The interaction between host, agent, and environment is effectively explained through the epidemiological triangle, which provides a foundational framework for understanding disease occurrence and transmission, as highlighted in Figure 4 illustrating the interrelationship among these three components (Texas A&M School of Public Health *et al.*, 2026). This model demonstrates that disease results from the dynamic interaction between a susceptible host, a causative agent, and an enabling environment, and that changes in any one of these factors can alter the risk of disease occurrence (LibreTexts *et al.*, 2025). Host factors such as immunity, genetics, and nutritional status influence susceptibility to infection, while agent characteristics including virulence, infectivity, and resistance determine the severity and spread of disease (Nature Research *et al.*, 2024). Environmental conditions, including climate, sanitation, and population density, create opportunities for interaction between host and agent, thereby facilitating or limiting disease transmission (MSD Veterinary Manual *et al.*, 2025). Veterinary public health utilizes this framework to design targeted intervention strategies aimed at breaking the chain of transmission by modifying one or more components of the epidemiological triangle (Kent State Public Health *et al.*, 2025). For instance,

vaccination programs strengthen host immunity, antimicrobial treatments target the causative agent, and environmental sanitation reduces exposure pathways, collectively contributing to disease control (Bonilla-Aldana *et al.*, 2020) ^[5]. Surveillance systems play a vital role in veterinary public health by enabling early detection of disease outbreaks and facilitating timely response measures, thereby reducing the impact on both animal and human populations (Mulenga *et al.*, 2022) ^[23]. Diagnostic services further support disease control by providing accurate identification of pathogens, which is essential for implementing appropriate treatment and prevention strategies (Kumar *et al.*, 2021) ^[19]. Preventive measures such as biosecurity, quarantine, and hygiene practices are widely promoted to minimize the risk of disease introduction and spread within animal populations and across the animal-human interface (Singh *et al.*, 2022) ^[30]. The integration of these approaches ensures a comprehensive response to zoonotic threats, enhancing the effectiveness of veterinary public health interventions (Narrod *et al.*, 2020) ^[24]. In addition, veterinary public health contributes to antimicrobial resistance control by promoting the rational use of antibiotics in animals, thereby reducing the risk of resistant pathogens affecting human health (McArthur *et al.*, 2021) ^[21]. The role of veterinary public health is particularly significant in low- and middle-income countries, where high dependence on livestock and limited healthcare infrastructure increase vulnerability to zoonotic diseases (Bardosh *et al.*, 2022) ^[3]. By strengthening institutional capacity, improving surveillance networks, and promoting community awareness, veterinary public health enhances resilience against emerging health threats (Rüegg *et al.*, 2018) ^[28]. Furthermore, the integration of modern technologies such as molecular diagnostics, geographic information systems, and digital surveillance platforms has improved the ability to monitor and control disease outbreaks in real time (Carlson *et al.*, 2022) ^[6]. Ultimately, veterinary public health plays a crucial role in reducing the burden of zoonotic diseases and enhancing community safety by combining scientific knowledge, policy interventions, and community engagement within a One Health framework (Destoumieux-Garzón *et al.*, 2018) ^[9].

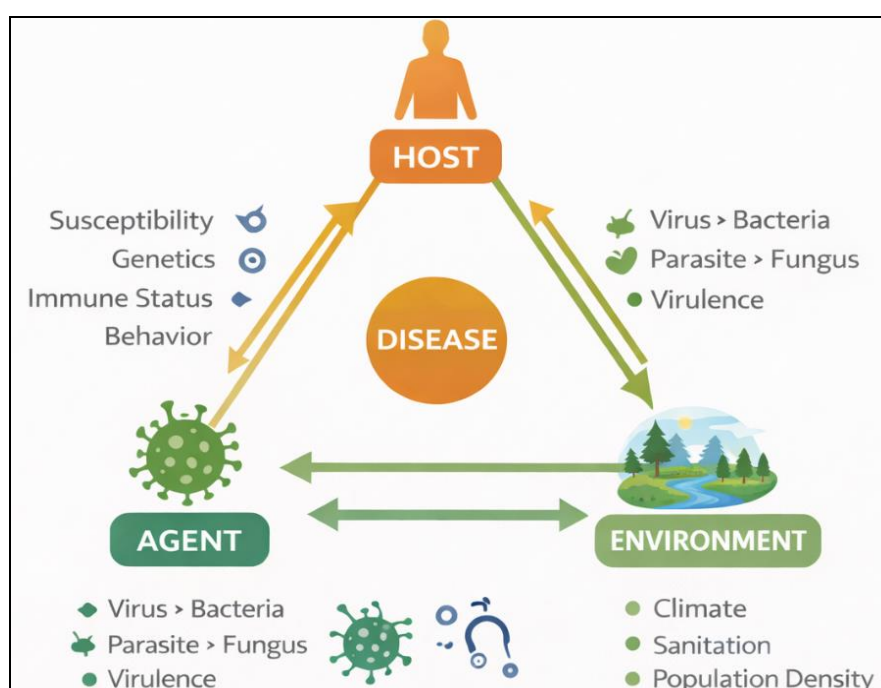


Fig 4: Epidemiological triangle depicting the interaction between host, agent, and environment in disease occurrence

Strategies for Zoonotic Disease Prevention

Effective prevention of zoonotic diseases requires a comprehensive and integrated approach that combines surveillance, vaccination, biosecurity, and community education to minimize risks at the human-animal-environment interface and ensure sustainable public health outcomes (WHO *et al.*, 2021) [36]. Integrated surveillance systems play a critical role in early detection and rapid response to disease outbreaks by enabling timely identification of emerging threats and facilitating coordinated interventions across sectors (FAO *et al.*, 2022) [10]. These systems rely on the systematic collection, analysis, and sharing of data from both animal and human health sectors, as conceptually illustrated in Figure 5, which demonstrates the flow of information

necessary for effective disease monitoring and control (CDC *et al.*, 2023) [7]. Early warning systems supported by digital technologies and real-time reporting tools have significantly improved the efficiency of surveillance mechanisms, allowing authorities to respond quickly to outbreaks and reduce their impact (McArthur *et al.*, 2021) [21]. Vaccination programs represent one of the most effective preventive strategies for controlling zoonotic diseases by enhancing immunity in animal populations and reducing the risk of transmission to humans (Zinsstag *et al.*, 2020) [40]. Mass vaccination campaigns targeting diseases such as rabies and brucellosis have demonstrated substantial success in lowering disease incidence and protecting vulnerable populations (Havelaar *et al.*, 2020) [14].

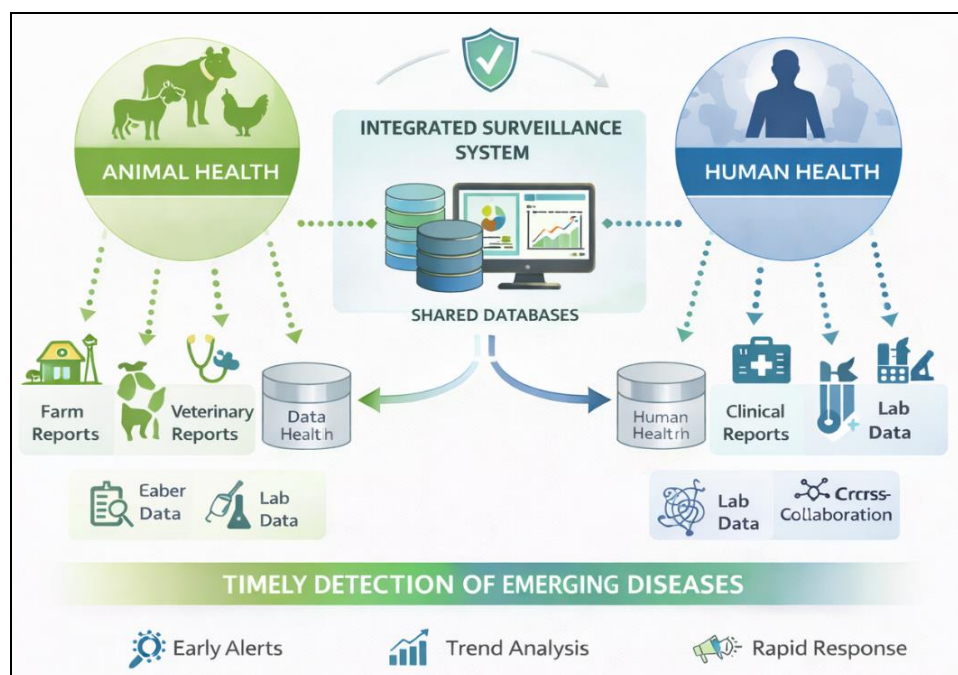


Fig 5: Integrated surveillance system demonstrating data flow between animal and human health sectors for early disease detection

Biosecurity measures are equally important in preventing the introduction and spread of pathogens within animal populations and across the animal-human interface (Singh *et al.*, 2022) [30]. These measures include controlled animal movement, proper sanitation, waste management, and the use of protective equipment, all of which contribute to reducing exposure to infectious agents (Kumar *et al.*, 2021) [19]. Community education and awareness programs are essential components of zoonotic disease prevention, as they empower individuals with knowledge about disease transmission, risk factors, and preventive practices (Bardosh *et al.*, 2022) [3]. Through targeted communication strategies and participatory approaches, communities can adopt safer behaviors such as proper hygiene, safe handling of animals, and timely reporting of disease symptoms (Narrod *et al.*, 2020) [24]. Preventive strategies are systematically organized in Table 2 within this section, highlighting key components such as awareness programs, immunization campaigns, hygiene practices, and veterinary extension services that collectively contribute to disease control (Mulenga *et al.*, 2022) [23]. Table 2 outlines major prevention strategies and their respective functions, emphasizing the importance of coordinated and multi-sectoral efforts in reducing disease transmission and improving public health outcomes (Bonilla-Aldana *et al.*, 2020) [5]. Veterinary extension plays a central role in implementing these strategies at the grassroots level by acting as a bridge between scientific

knowledge and community practices (Kock *et al.*, 2020). Extension workers provide training, advisory services, and technical support to farmers and livestock owners, enabling them to adopt recommended practices for disease prevention and animal health management (Rüegg *et al.*, 2018) [28]. The effectiveness of these interventions is enhanced through participatory approaches that involve communities in decision-making processes and encourage ownership of health initiatives (Thumbi *et al.*, 2019) [32]. In addition, veterinary extension supports the integration of traditional knowledge with modern scientific practices, thereby ensuring culturally appropriate and context-specific solutions for zoonotic disease prevention (Grace *et al.*, 2017) [13]. The use of digital tools and mobile-based platforms has further strengthened extension services by improving communication, data collection, and dissemination of information to remote and underserved areas (Zhou *et al.*, 2025) [39]. These innovations enable real-time monitoring of disease outbreaks and facilitate rapid response, thereby enhancing the overall effectiveness of prevention strategies (Liang *et al.*, 2026) [20]. Furthermore, intersectoral collaboration among veterinary, medical, and environmental professionals is essential for the successful implementation of integrated prevention approaches within the One Health framework (Destoumieux-Garzón *et al.*, 2018) [9]. Policy support and adequate resource allocation are also critical for sustaining prevention efforts and ensuring the scalability of

successful interventions (World Bank *et al.*, 2020) [35]. Capacity building through training programs and institutional strengthening is necessary to equip professionals with the skills required to address emerging zoonotic threats effectively (Salyer *et al.*, 2017) [29]. The integration of surveillance, vaccination, biosecurity, and community education within a coordinated framework enhances the resilience of health systems and reduces the burden of zoonotic diseases on communities (Varela *et al.*, 2022) [33]. Ultimately, a comprehensive and collaborative approach to zoonotic disease prevention, supported by strong veterinary extension systems, is essential for safeguarding public health, improving livelihoods, and ensuring sustainable development in both rural and urban settings (Zinsstag *et al.*, 2020) [40].

Table 2: Key strategies for zoonotic disease prevention and their functional roles

Strategy	Function
Surveillance Systems	Early detection and monitoring of disease outbreaks
Vaccination Programs	Enhancing immunity and reducing disease spread
Biosecurity Measures	Preventing introduction and spread of pathogens
Hygiene Practices	Reducing environmental contamination and exposure
Awareness Programs	Educating communities about risks and prevention
Veterinary Extension	Facilitating knowledge transfer and behavior change

One health approach in practice

The One Health approach emphasizes the integration of human, animal, and environmental health systems to address complex health challenges such as zoonotic diseases by recognizing their deep interconnections and shared determinants across ecosystems (WHO *et al.*, 2023) [38]. It is defined as a collaborative, multispectral, and trans disciplinary approach that operates at local, national, and global levels to achieve optimal health outcomes by linking people, animals, plants, and their shared environment (CDC *et al.*, 2025) [8]. This approach has gained global recognition as an essential framework for preventing and controlling zoonotic diseases, which arise at the interface of human, animal, and environmental systems (Thal *et al.*, 2023). The need for such integration is driven by increasing environmental changes, agricultural expansion, and human activities that create new opportunities for disease emergence and transmission (WHO *et al.*, 2022) [37]. The collaborative nature of One Health is visually represented in Figure 6, which illustrates the interconnected roles of different sectors including veterinary services, human healthcare, environmental management, and policy frameworks working together in disease prevention and control (FAO *et al.*, 2025) [11]. By fostering interdisciplinary collaboration, the One Health approach enables coordinated surveillance, improved communication, and efficient resource utilization, thereby enhancing the effectiveness of public health interventions (WHO *et al.*, 2023) [38]. Integrated surveillance systems under this framework allow for early detection of zoonotic threats by combining data from multiple sectors, improving preparedness and response to outbreaks (FAO *et al.*, 2025) [11]. Furthermore, the approach supports the development of comprehensive strategies that address not only disease control but also food safety, antimicrobial resistance, and environmental sustainability (WHO *et al.*, 2023) [38]. The

effectiveness of One Health lies in its ability to bridge gaps between traditionally separate disciplines, ensuring that interventions are holistic and sustainable rather than fragmented and reactive (WHO EMRO *et al.*, 2020). Veterinary extension plays a crucial role in supporting this approach by facilitating communication and coordination among stakeholders, including farmers, veterinarians, public health officials, and policymakers, thereby strengthening the implementation of integrated health strategies (CDC *et al.*, 2025) [8]. Through education and outreach programs, veterinary extension helps translate complex scientific concepts into practical knowledge that can be applied at the community level, promoting awareness and behavioral change (FAO *et al.*, 2025) [11]. It also enhances community participation by encouraging local stakeholders to actively engage in disease prevention and control efforts, thereby improving the effectiveness of interventions (WHO *et al.*, 2023). In addition, veterinary extension supports the implementation of biosecurity measures, vaccination campaigns, and surveillance activities that are essential components of the One Health framework (Thal *et al.*, 2023). The integration of digital technologies such as mobile health platforms and data-sharing systems has further strengthened the role of veterinary extension in facilitating real-time communication and monitoring of disease outbreaks (FAO *et al.*, 2025) [11]. Despite its advantages, the implementation of the One Health approach faces challenges including limited resources, lack of coordination, and insufficient infrastructure in many regions, particularly in developing countries (WHO EMRO *et al.*, 2020). Addressing these challenges requires strong political commitment, adequate funding, and capacity building to support interdisciplinary collaboration and integrated health systems (CDC *et al.*, 2025). The growing recognition of One Health as a key strategy for managing zoonotic diseases and other health threats underscores its importance in achieving global health security and sustainable development goals (WHO *et al.*, 2022) [37]. Ultimately, the One Health approach represents a transformative paradigm that integrates science, policy, and community engagement to address complex health challenges in a comprehensive and sustainable manner, ensuring improved health outcomes for humans, animals, and the environment (WHO *et al.*, 2023) [38].



Fig 6: One Health operational model showing collaboration among human, animal, and environmental health sectors

Role of Veterinary Extension in Community Safety

Veterinary extension plays a vital role in promoting community safety by enhancing awareness, improving animal health practices, and supporting public health initiatives through structured education, outreach, and participatory engagement at the grassroots level (Noah *et al.*, 2025). It serves as a critical bridge between scientific knowledge and local practices, ensuring that communities understand zoonotic risks and adopt preventive behaviors that reduce disease transmission (Hossain *et al.*, 2025). Extension workers act as intermediaries between government agencies and communities, facilitating the implementation of health programs, policies, and disease control measures in a culturally appropriate and accessible manner (Arya *et al.*, 2024) ^[2]. These professionals play an essential role in disseminating information on vaccination, hygiene, and biosecurity practices, thereby strengthening local capacity to prevent and manage zoonotic diseases (Garcia-Sanchez *et al.*, 2023). The effectiveness of veterinary extension is largely dependent on its ability to engage communities through participatory approaches that encourage knowledge sharing, local involvement, and behavioral change (Kim *et al.*, 2025) ^[17]. Through regular training programs and awareness campaigns, extension services improve farmers' understanding of disease transmission pathways and the importance of preventive measures, ultimately contributing to improved public health outcomes (Singh *et al.*, 2024) ^[30]. The impact of these interventions is illustrated in Figure 7, which presents a community-level model of veterinary extension activities, highlighting how education, surveillance, and health practices collectively reduce zoonotic risks and enhance community safety (Hossain *et al.*, 2025). Veterinary extension also strengthens surveillance systems by encouraging early reporting of disease symptoms and facilitating communication between local communities and health authorities (Mulenga *et al.*, 2022) ^[23]. This early detection capability is crucial for preventing outbreaks and minimizing their impact on both human and animal populations (Rodriguez-Morales *et al.*, 2025). In addition, extension workers promote safe animal handling practices and

proper waste management, which are essential for reducing environmental contamination and limiting the spread of infectious agents (BMC Veterinary Research *et al.*, 2025). Community-based interventions supported by veterinary extension have been shown to improve compliance with public health guidelines, particularly in resource-limited settings where access to formal healthcare services may be restricted (Arya *et al.*, 2024) ^[2]. The integration of veterinary extension within the One Health framework further enhances its effectiveness by promoting collaboration among human health professionals, veterinarians, and environmental experts (Hossain *et al.*, 2025). This interdisciplinary approach ensures that interventions address multiple determinants of disease transmission, leading to more sustainable and comprehensive health outcomes (Mulenga *et al.*, 2022) ^[23]. Capacity-building programs implemented through veterinary extension empower communities with the skills and knowledge needed to take proactive measures in disease prevention and health promotion (Kim *et al.*, 2025) ^[17]. These programs often include training in animal health management, vaccination schedules, and recognition of early disease symptoms, enabling communities to respond effectively to potential health threats (Garcia-Sanchez *et al.*, 2023). Furthermore, veterinary extension contributes to improving food safety by promoting hygienic production practices and reducing contamination risks in animal-derived products (Noah *et al.*, 2025). The use of modern technologies such as mobile-based advisory systems and digital surveillance tools has further enhanced the reach and efficiency of extension services, allowing real-time communication and rapid dissemination of information (Mulenga *et al.*, 2022) ^[23]. By fostering trust and collaboration between communities and health systems, veterinary extension strengthens the overall resilience of communities against zoonotic disease threats (Arya *et al.*, 2024) ^[2]. Ultimately, veterinary extension empowers communities to adopt safe, informed, and sustainable practices that reduce zoonotic risks, improve animal and human health, and contribute to long-term public health security (Singh *et al.*, 2024) ^[30].



Fig 7: Community-level veterinary extension model highlighting interventions for improving public health safety

Challenges in Zoonotic Disease Prevention

Despite significant advancements in veterinary and public health systems, several persistent challenges continue to hinder effective zoonotic disease prevention, particularly in low- and middle-income countries where health infrastructure and resources remain limited (WHO *et al.*, 2021) [36]. Limited financial resources restrict the implementation of large-scale surveillance, vaccination, and awareness programs, thereby weakening the overall capacity to prevent and control zoonotic diseases (World Bank *et al.*, 2020) [35]. Inadequate infrastructure, including insufficient laboratory facilities, poor transportation networks, and lack of cold chain systems, further constrains timely diagnosis and response to disease outbreaks (FAO *et al.*, 2022) [10]. The shortage of trained personnel, including veterinarians, epidemiologists, and public health professionals, significantly affects the efficiency of disease surveillance and intervention strategies (Mulenga *et al.*, 2022) [23]. Poor coordination among sectors such as

veterinary services, human healthcare, and environmental agencies remains a major barrier, limiting the effectiveness of integrated approaches like One Health (Destoumieux-Garzón *et al.*, 2018) [9]. Socio-cultural factors, including traditional farming practices, close human-animal interactions, and resistance to behavioral change, further complicate zoonotic disease control efforts (Bardosh *et al.*, 2022) [3]. Low levels of awareness among farmers and communities about zoonotic risks and preventive measures contribute to delayed reporting and increased transmission of diseases (Singh *et al.*, 2022) [30]. These challenges are systematically summarized in Figure 8, which highlights key barriers affecting the implementation of prevention strategies and underscores the need for targeted interventions (Zinsstag *et al.*, 2020) [40]. Weak surveillance systems remain a critical issue, as fragmented data collection and lack of integration between animal and human health sectors limit early detection and timely response to outbreaks (Rüegg *et al.*, 2018) [28].

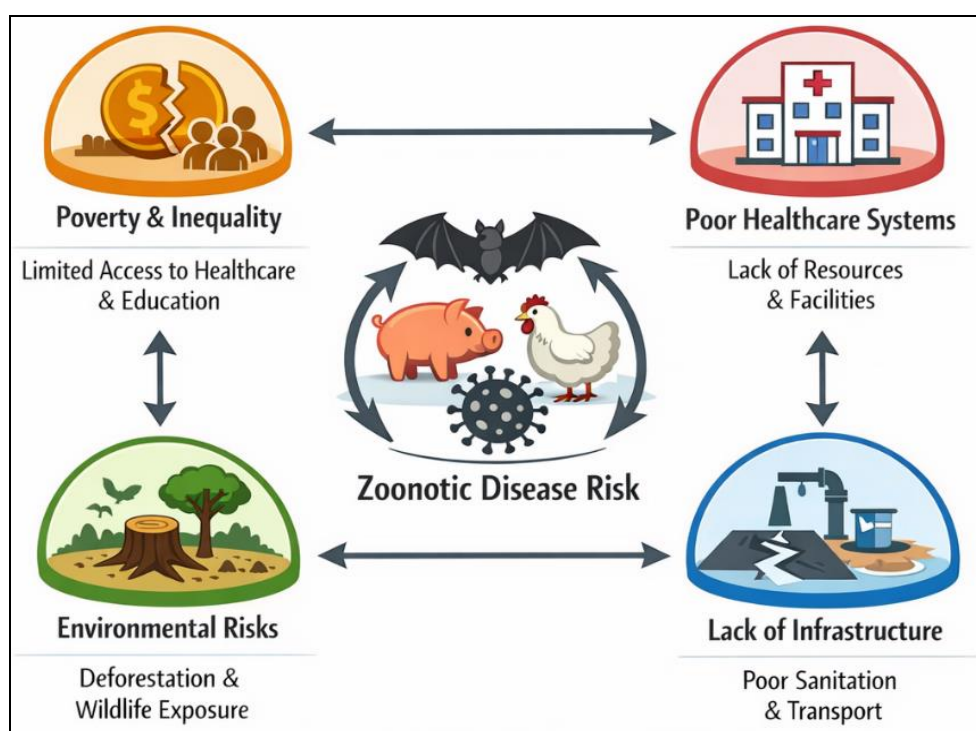


Fig 8: Key challenges affecting zoonotic disease prevention including socio-economic and infrastructural barriers

In many regions, underreporting of zoonotic diseases due to inadequate monitoring systems and lack of incentives for reporting further exacerbates the problem (Salzer *et al.*, 2017) [29]. Resource constraints also affect the availability of essential veterinary services, vaccines, and diagnostic tools, reducing the effectiveness of disease control programs (Narrod *et al.*, 2020) [24]. Table 3 provides a comprehensive overview of these challenges along with potential solutions, offering practical insights for improving zoonotic disease prevention strategies (Bonilla-Aldana *et al.*, 2020) [5]. For instance, lack of awareness can be addressed through community education programs and veterinary extension services that promote knowledge sharing and behavioral change (Kumar *et al.*, 2021) [19]. Weak surveillance systems can be strengthened through the adoption of digital technologies, mobile-based reporting tools, and integrated data-sharing platforms that enhance real-time monitoring and response (McArthur *et al.*, 2021) [21]. Resource constraints can be mitigated through increased government funding, international collaboration, and public-private partnerships

that support the development of infrastructure and capacity building (World Bank *et al.*, 2020) [35]. Policy support plays a crucial role in addressing these challenges by providing a framework for coordinated action, resource allocation, and implementation of integrated health strategies (WHO *et al.*, 2022) [37]. Capacity-building initiatives, including training programs and professional development, are essential for improving the skills and competencies of personnel involved in zoonotic disease control (Thumbi *et al.*, 2019) [32]. Strengthening community engagement through participatory approaches and local involvement enhances the acceptance and sustainability of prevention strategies (Grace *et al.*, 2017) [13]. The integration of modern technologies such as geographic information systems, remote sensing, and artificial intelligence has the potential to improve disease surveillance and predictive modeling, enabling more effective intervention planning (Carlson *et al.*, 2022) [6]. Addressing socio-cultural barriers requires culturally sensitive approaches that respect local traditions while promoting safe practices and health awareness (Bardosh *et al.*, 2022) [3]. The implementation of

biosecurity measures and improved animal husbandry practices can significantly reduce the risk of disease transmission at the farm level (Havelaar *et al.*, 2020) ^[14]. Strengthening international collaboration and information sharing is also critical for managing transboundary zoonotic diseases and ensuring global health security (FAO *et al.*, 2022) ^[10]. Table 3, which outlines major challenges such as lack of awareness, weak surveillance systems, and resource constraints along with corresponding solutions including education programs, digital technologies, and policy support, provides a strategic roadmap for strengthening veterinary public health systems and improving community safety (Zinsstag *et al.*, 2020) ^[40]. Ultimately, overcoming these challenges requires a comprehensive and coordinated approach that integrates scientific knowledge, policy interventions, and community participation to enhance the effectiveness of zoonotic disease prevention efforts and ensure sustainable public health outcomes (Destoumieux-Garzón *et al.*, 2018) ^[9].

Table 3: Challenges in zoonotic disease control along with proposed solutions

Challenge	Proposed Solution
Lack of Awareness	Community education and training programs
Weak Surveillance Systems	Digital monitoring and integrated reporting systems
Limited Resources	Increased funding and public-private partnerships
Inadequate Infrastructure	Development of laboratories and logistics support
Poor Intersectoral Coordination	Strengthening One Health collaboration frameworks
Shortage of Skilled Personnel	Capacity building and professional training programs

Future Directions

Future strategies for zoonotic disease prevention should focus on strengthening One Health frameworks, enhancing digital surveillance systems, and promoting community participation to effectively address emerging global health threats and improve resilience across interconnected systems (FAO *et al.*, 2025) ^[11]. Strengthening One Health frameworks requires deeper integration of human, animal, and environmental health sectors through coordinated policies, shared resources, and interdisciplinary collaboration (WHO *et al.*, 2023) ^[38]. This integrated approach enables more comprehensive risk assessment and targeted interventions that address the root causes of zoonotic disease emergence rather than relying solely on reactive measures (Rai *et al.*, 2024) ^[26]. Enhancing digital surveillance systems is a critical priority, as traditional methods are often insufficient for early detection of emerging zoonotic threats and rapid response to outbreaks (Bartlett and Uhart, 2024). Advanced digital platforms enable real-time data collection, analysis, and sharing across sectors, improving the efficiency and accuracy of disease monitoring systems (FAO *et al.*, 2025) ^[11]. The incorporation of artificial intelligence into surveillance systems offers significant potential for predictive modeling, pattern recognition, and early warning of disease outbreaks, thereby improving preparedness and response strategies (Frontiers Public Health *et al.*, 2025) ^[17]. Artificial intelligence-driven tools can integrate large datasets from multiple sources, including environmental, animal, and human health data, to identify emerging risks and support decision-making processes (Melchane *et al.*, 2024). Mobile health applications also play a crucial role in enhancing surveillance and communication

by enabling real-time reporting of disease cases, facilitating rapid dissemination of information, and improving accessibility in remote and underserved areas (FAO *et al.*, 2025) ^[11]. These technologies are particularly valuable in low-resource settings, where traditional infrastructure may be limited but mobile connectivity is increasing (PMC *et al.*, 2025). Promoting community participation is another essential component of future strategies, as local communities are often the first to detect and respond to disease outbreaks (Frontiers Public Health *et al.*, 2025) ^[17]. Community-based surveillance systems enhance early detection and reporting of zoonotic diseases by involving local stakeholders in monitoring and response activities (FAO *et al.*, 2025) ^[11]. Participatory approaches also improve the adoption of preventive measures by fostering trust, awareness, and ownership among community members (WHO *et al.*, 2022) ^[37]. Capacity building is critical for strengthening both institutional and community-level responses to zoonotic diseases, as it equips professionals and stakeholders with the knowledge and skills required to implement effective prevention strategies (Mulenga *et al.*, 2022) ^[23]. Training programs, field epidemiology initiatives, and professional development opportunities are essential for improving workforce competency and ensuring preparedness for emerging health threats (FAO *et al.*, 2025) ^[11]. Research and innovation will continue to play a key role in advancing zoonotic disease prevention by providing evidence-based insights into disease dynamics, transmission pathways, and effective intervention strategies (Rai *et al.*, 2024). Interdisciplinary research that integrates veterinary science, public health, environmental science, and data analytics is particularly important for addressing complex health challenges (WHO *et al.*, 2023) ^[37]. Policy integration is also essential for aligning national and international efforts, ensuring coordinated action, and providing the necessary regulatory frameworks and funding mechanisms to support prevention strategies (FAO *et al.*, 2025) ^[11]. Strong political commitment and governance structures are required to implement these policies effectively and sustain long-term health initiatives (WHO *et al.*, 2022) ^[37]. Veterinary extension will continue to play a key role in facilitating these advancements by bridging the gap between innovation and implementation at the community level (Frontiers Public Health *et al.*, 2025). Extension services translate complex scientific knowledge into practical applications, ensuring that technological and policy advancements are effectively adopted by farmers and communities (FAO *et al.*, 2025) ^[11]. They also support the dissemination of information, training, and capacity-building activities that enhance community awareness and participation in disease prevention efforts (Mulenga *et al.*, 2022) ^[23]. The integration of digital tools within veterinary extension further enhances its effectiveness by enabling real-time communication, data sharing, and monitoring of disease trends (PMC *et al.*, 2025). Ultimately, future strategies for zoonotic disease prevention must adopt a holistic and forward-looking approach that combines technological innovation, community engagement, and policy support within a strong One Health framework to ensure sustainable public health outcomes and global health security (FAO *et al.*, 2025) ^[11].

Conclusion

Veterinary extension and public health play a crucial role in the prevention of zoonotic diseases and the promotion of community safety by addressing health challenges at the

interface of humans, animals, and the environment. Veterinary extension serves as a bridge between scientific knowledge and community practices, ensuring that farmers, livestock owners, and the general public are informed about disease risks and preventive measures. Through education and awareness programs, individuals are encouraged to adopt safe animal handling practices, maintain hygiene, and participate in vaccination and biosecurity initiatives. At the same time, veterinary public health focuses on controlling diseases at their animal source, ensuring food safety, and reducing environmental risks that contribute to disease transmission. The integration of surveillance systems enhances early detection and rapid response to outbreaks, minimizing their impact on both human and animal populations. The adoption of the One Health approach further strengthens these efforts by promoting collaboration among veterinary, medical, and environmental sectors, leading to more comprehensive and sustainable health solutions. Technological advancements, including digital surveillance tools and mobile-based communication systems, have improved the efficiency of monitoring and intervention strategies. Additionally, strong policy support and institutional frameworks are necessary to ensure the effective implementation of prevention programs. By combining interdisciplinary collaboration, community participation, and innovative approaches, veterinary extension and public health systems can significantly reduce the burden of zoonotic diseases and contribute to the overall well-being and resilience of communities.

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