

Infectious Diseases in Water Buffalo: A Review of Current Control Strategies

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Abstract Water buffaloes play a crucial role in global agriculture and dairy production, but infectious diseases pose significant challenges to their health, productivity, and farmers' livelihoods. This study summarizes the current status of control strategies for major infectious diseases affecting water buffaloes, including bacterial, viral, and parasitic infections such as brucellosis, foot-and-mouth disease, and liver fluke disease. It explores existing measures such as vaccination, antimicrobial therapy, and biosafety practices, while emphasizing limitations such as antibiotic resistance and inadequate veterinary infrastructure. Taking a study in South Asia as an example, it illustrates the impact of regional control strategies, including vaccination campaigns and community led initiatives, in reducing disease prevalence and strengthening farmer practices. This study aims to emphasize the advancement of diagnostic technology, disease resistant gene breeding, and international cooperation in formulating comprehensive policies that require comprehensive and sustainable strategies to improve the health, productivity, and ecological contribution of water buffaloes.

Keywords Water buffalo; Infectious diseases; Disease control; Zoonotic risks; Vaccination

1 Introduction

Water buffaloes (*Bubalus bubalis*) are vital to the agricultural economies of many countries, particularly in Asia and South America. However, they are susceptible to a range of infectious diseases that can significantly impact their health and productivity. Schistosomiasis, caused by *Schistosoma japonicum*, is a notable zoonotic parasitic disease where water buffaloes act as major reservoirs. *Coccidiosis*, caused by various *Eimeria* species, is another prevalent disease leading to diarrhea and other gastrointestinal issues (Dubey, 2018). Additionally, water buffaloes are hosts to *Babesia bovis*, a tick-borne parasite, which they often carry asymptotically (Benítez et al., 2018). Other significant diseases include paratuberculosis, which has a high prevalence in certain regions, and *Trypanosoma vivax*, which can cause severe outbreaks under stressful conditions. *Babesia orientalis*, a recently identified species in China, also poses a threat to water buffalo health (He et al., 2017). Furthermore, infections by *Neospora caninum* and *Toxoplasma gondii* have been linked to reproductive issues such as abortion and embryonic death (Ciuca et al., 2020).

Addressing infectious diseases in water buffalo is crucial for several reasons. Firstly, these diseases can lead to significant economic losses due to decreased productivity, increased veterinary costs, and mortality (Galon et al., 2019). For instance, the high seroprevalence of paratuberculosis in Italian water buffaloes suggests a need for urgent control measures to prevent economic losses (Martucciello et al., 2021). Secondly, water buffaloes are often asymptomatic carriers of diseases like *Babesia bovis* and *Trypanosoma vivax*, which can complicate disease management and control efforts (Garcia et al., 2016). Thirdly, zoonotic diseases such as schistosomiasis pose a public health risk, making it imperative to control these infections in water buffaloes to protect human health (He et al., 2018). Lastly, reproductive diseases caused by pathogens like *Neospora caninum* and *Toxoplasma gondii* can severely impact herd fertility and productivity, necessitating targeted control strategies (Kengradomkij et al., 2015).

This study provides a comprehensive overview of current control strategies for buffalo infectious diseases, covering the examination of the epidemiology, diagnosis, and treatment of key diseases such as schistosomiasis, coccidiosis, babesiosis, paratuberculosis, trypanosomiasis, and infections caused by *Neospora caninum* and *Toxoplasma gondii*, also explores the effectiveness of various control measures, including vaccination, chemotherapeutic treatments, and management practices. This study aims to highlight the current knowledge gap and propose directions for future research to improve disease control in water buffalo populations.

2 Major Infectious Diseases in Water Buffalo

2.1 Bacterial diseases

Water buffaloes are susceptible to various bacterial infections, which can significantly impact their health and productivity. One notable bacterial disease is paratuberculosis, a chronic enteric disease affecting ruminants. A study conducted in the Campania region of Italy found a high herd-level prevalence of paratuberculosis in water buffaloes, with an apparent prevalence of 54.7% at the herd level and 1.8% at the animal level. This suggests the need for urgent adoption of herd-control programs to manage this disease effectively (Martucciello et al., 2021). Another significant bacterial pathogen is *Anaplasma marginale*, which was detected in 29% of water buffalo blood samples in the Philippines. This pathogen is known to cause tick-borne diseases, and its high prevalence highlights the importance of surveillance and prevention programs (Galon et al., 2019).

2.2 Viral diseases

While the provided data does not include specific studies on viral diseases in water buffaloes, it is well-documented in the literature that water buffaloes can be affected by various viral infections, such as foot-and-mouth disease (FMD) (Damaty et al., 2021) and bovine viral diarrhoea (BVD). These diseases can lead to severe economic losses due to decreased productivity and increased mortality rates. Effective vaccination and biosecurity measures are essential to control the spread of these viral infections in water buffalo populations.

2.3 Parasitic diseases

Parasitic infections are a major concern for water buffalo health, with several studies highlighting their prevalence and impact. Schistosomiasis, caused by *Schistosoma japonicum*, is a significant zoonotic parasitic disease. Research has shown that water buffaloes can develop resistance to reinfection with *S. japonicum* after initial exposure and treatment with *Praziquantel*, suggesting the potential for vaccine development (McWilliam et al., 2013; He et al., 2018). Another important parasitic disease is babesiosis, caused by *Babesia* species. Water buffaloes infected with *Babesia bovis* showed no or significantly mitigated clinical symptoms compared to bovines, indicating an efficient innate immune response (Benítez et al., 2018). Additionally, infections with *Neospora caninum* and *Toxoplasma gondii* have been associated with reproductive losses in water buffaloes, including abortion and embryonic death (Ciuca et al., 2020; Inpankaew et al., 2021). *Trypanosoma vivax* has also been reported to cause severe acute infections in water buffaloes during stressful conditions, such as prolonged droughts, leading to significant mortality (Garcia et al., 2016). Lastly, *Fasciola gigantica*, a tropical liver fluke, has been shown to induce significant immune responses in infected buffaloes, with upregulated immune-related pathways in various tissues (Hu et al., 2022).

3 Current Control Strategies

3.1 Vaccination

Vaccination is a critical strategy in controlling infectious diseases in water buffalo. For instance, the use of Bovine alphaherpesvirus 1 (BoHV-1) gE-deleted marker vaccines has been explored to protect water buffalo against *Bubaline alphaherpesvirus 1* (BuHV-1). In a study, water buffaloes immunized with these vaccines showed early humoral immunity and reduced viral shedding compared to unvaccinated controls, indicating potential protective

capabilities, although not complete protection against wild-type BuHV-1 (Martucciello et al., 2023). Additionally, research into the immune responses of water buffalo against *Schistosoma japonicum* larvae has provided crucial insights for vaccine design, suggesting that a transmission-blocking vaccine could significantly aid in controlling schistosomiasis (McWilliam et al., 2013). The self-cure phenomenon observed in water buffaloes infected with *S. japonicum*, where the worm burden drops sharply due to immune responses, also highlights the potential for developing effective vaccines targeting this parasite.

3.2 Antimicrobial and antiparasitic treatments

Antimicrobial and antiparasitic treatments are essential in managing infections in water buffalo. Praziquantel (PZQ) is commonly used to treat schistosomiasis, and studies have shown that water buffaloes develop significant resistance to reinfection after treatment, primarily due to acquired immunity (He et al., 2018). For *Trypanosoma evansi* infection, Berenil® has demonstrated a 100% cure rate, making it a highly effective treatment option, whereas Trypanidium® showed only a 40% cure rate (Nguyen et al., 2013). These treatments are crucial in reducing the prevalence and impact of parasitic diseases in water buffalo populations.

3.3 Biosecurity measures

Biosecurity measures play a vital role in preventing the spread of infectious diseases among water buffalo. In China, control strategies for schistosomiasis include barrier farming to prevent grazing in transmission areas and replacing water buffaloes with mechanized tractors to reduce the risk of infection (Li et al., 2014). Additionally, the molecular characterization of foot and mouth disease virus (FMDV) in Egyptian water buffaloes has highlighted the importance of monitoring and controlling new viral strains to prevent outbreaks (Damaty et al., 2021). Implementing strict biosecurity protocols, such as regular health screenings, quarantine measures for new or sick animals, and maintaining clean and hygienic farm environments, can significantly reduce the risk of disease transmission (Kumar et al., 2021).

4 Challenges in Disease Control

4.1 Lack of veterinary infrastructure

The control of infectious diseases in water buffalo is significantly hampered by inadequate veterinary infrastructure. In many regions, especially in developing countries, there is a shortage of veterinary professionals and facilities equipped to diagnose and treat diseases effectively. This lack of infrastructure leads to underreporting and mismanagement of diseases, exacerbating their impact on livestock health and productivity. For instance, the prevalence of tick-borne pathogens in water buffaloes in the Philippines highlights the need for better diagnostic and treatment facilities to manage these infections effectively (Galon et al., 2019).

4.2 Emerging and re-emerging diseases

Emerging and re-emerging diseases pose a continuous threat to water buffalo populations. Diseases such as *Trypanosoma vivax*, which typically cause asymptomatic infections, can lead to severe outbreaks under stressful conditions like prolonged droughts, as observed in Venezuela (Garcia et al., 2016). Additionally, zoonotic diseases such as leptospirosis, brucellosis, and bovine tuberculosis not only affect animal health but also pose significant public health risks (Martucciello et al., 2021; Fang, 2024). The emergence of these diseases often goes unnoticed until they cause substantial economic losses and health issues, underscoring the need for vigilant monitoring and rapid response strategies.

4.3 Socioeconomic and cultural factors

Socioeconomic and cultural factors also play a crucial role in the control of infectious diseases in water buffalo. In many regions, traditional farming practices and the close interaction between humans and animals facilitate the

spread of zoonotic diseases. For example, the presence of cats on farms has been identified as a risk factor for *Toxoplasma gondii* infection in water buffalo, which can be transmitted to humans through unprocessed milk and meat (De Barros et al., 2020). Moreover, the economic burden of implementing comprehensive disease control programs can be prohibitive for small-scale farmers, leading to inadequate disease management and persistent infection cycles (Shi et al., 2021). Cultural practices, such as the use of buffaloes for draft power and their integration into household systems, further complicate disease control efforts (Li et al., 2014).

5 Case Study: Regional Disease Management in South Asia

5.1 Overview of the selected region

South Asia, particularly countries like India, Thailand, and the Philippines, is a region where water buffaloes play a crucial role in agriculture and dairy production. The climate and agricultural practices in these areas make them susceptible to various infectious diseases that affect water buffaloes, which in turn impacts both the economy and public health. For instance, in India, water buffaloes are the main dairy animals, and their health is vital for the dairy industry (Dubey, 2018). Similarly, in Thailand, water buffaloes are essential draft animals for agriculture, especially in resource-restricted areas (Kengradomkij et al., 2015).

5.2 Control strategies implemented

In South Asia, several control strategies have been implemented to manage infectious diseases in water buffaloes. In Kerala, India, an outbreak of *Theileria orientalis* was managed through therapeutic interventions using anti-theilerial drugs such as buparvaquone and oxytetracycline, which led to the recovery of animals in the early stages of the disease. In Thailand, the control of *Neospora caninum* involved seroprevalence studies to identify risk factors and implement targeted interventions to reduce exposure. In the Philippines, molecular detection and characterization of tick-borne pathogens like *Anaplasma marginale*, *Babesia bovis*, and *B. bigemina* have been crucial for crafting effective surveillance and prevention programs (Galon et al., 2019). Additionally, vaccination strategies have been employed in China to combat schistosomiasis, with trials showing that a two-dose prime-boost regimen can significantly reduce worm and egg burdens in water buffaloes (Table 1) (Da'dara et al., 2019).

Table 1 Comparison of time between vaccinations: 1 month (regular) or 3 months (extended) (Adopted from Da'dara et al., 2019)

Group	(time n between injections)	Worms		Liver eggs		Miracidia	
		Total worms per animal (X±SD)	Reduction and Statistics	Eggs per gram liver (X±SD)	Reduction and Statistics	Eggs per gram feces (X±SD)	Reduction and Statistics
Mock (extended)	9	454.44±19.42	-	464.11±98.43	-	26.00±7.00	-
pVAX (extended)	9	454.67±15.18	-	486.11±103.99	-	26.67±6.00	-
pSjC23-Hsp70 (extended)	11	285.27±30.19	37.23% p < 0.0001	323.00±40.91	30.4% p < 0.0001	17.82±5.40	31.46% p < 0.01
pSjC23-Hsp70 (regular)	11	267.27±30.46	41.19% p < 0.0001	290.09±45.68	37.5% p < 0.0001	14.09±2.43	45.81% p < 0.001

Note: pL-12 was administered at the prime for all groups but mock. *p*-value compared to mock by one-way ANOVA and Turkey's post-test. No significant difference between extended and regular (Adopted from Da'dara et al., 2019)

5.3 Outcomes and lessons learned

The control strategies implemented in South Asia have yielded mixed outcomes. In Kerala, the use of anti-theilerial drugs was effective in reducing mortality rates among water buffaloes affected by *Theileria orientalis*, highlighting the importance of early detection and treatment (Vinodkumar et al., 2015). In Thailand, the identification of risk factors for *Neospora caninum* exposure has helped in formulating localized control measures, although the overall seroprevalence remains a concern. The molecular characterization of tick-borne pathogens in

the Philippines has provided baseline data essential for developing targeted control programs, although the high prevalence of these pathogens indicates the need for ongoing surveillance and intervention. The vaccination trials in China have shown promise in reducing schistosomiasis transmission, suggesting that vaccination could be a key component of integrated control strategies. These experiences underscore the importance of a multifaceted approach, combining early detection, targeted treatment, vaccination, and continuous surveillance to effectively manage infectious diseases in water buffaloes in South Asia (Silveira et al., 2016).

6 Future Directions in Infectious Disease Management

6.1 Advancements in diagnostics

Recent advancements in diagnostic techniques have significantly improved the detection and management of infectious diseases in water buffalo (Huang and Lin, 2024). For instance, the development of the recombinase polymerase amplification-lateral flow dipstick (RPA-LF) assay for *Babesia orientalis* has shown high sensitivity and specificity, making it a valuable tool for rapid field detection (An et al., 2021). Similarly, the use of glutathione-S-transferase (GST) as a diagnostic antigen for liver amphistome *Gigantocotyle explanatum* has demonstrated high immunogenicity and specificity, providing a reliable alternative to traditional fecal egg count methods (Rehman et al., 2020). Additionally, molecular assays have been employed to detect and characterize tick-borne pathogens such as *Anaplasma marginale*, *Babesia bovis*, and *Babesia bigemina*, offering detailed insights into the prevalence and genetic diversity of these pathogens (Galon et al., 2019).

6.2 Innovative disease prevention methods

Innovative approaches to disease prevention are crucial for managing infectious diseases in water buffalo. The use of immunophenotyping to understand lymphocyte alterations in buffalo with brucellosis has opened new avenues for targeted immunotherapies (Grandoni et al., 2023). Experimental studies have also shown that water buffaloes exhibit mitigated clinical symptoms to *Babesia bovis* infections, suggesting that these animals possess efficient innate immune mechanisms that could be harnessed for developing new preventive strategies (Benítez et al., 2018). Furthermore, the identification of specific molecular markers and the development of vaccines against pathogens like *Babesia orientalis* are ongoing efforts aimed at reducing the incidence of these diseases (He et al., 2017).

6.3 International collaboration and policy development

International collaboration and policy development are essential for the effective management of infectious diseases in water buffalo. The high seroprevalence of *Neospora caninum* and *Toxoplasma gondii* in water buffaloes in southern Italy highlights the need for coordinated efforts to address parasitic infections that impact reproductive health (Ciuca et al., 2020). The first molecular detection and characterization of tick-borne pathogens in the Philippines underscore the importance of global surveillance and data sharing to craft effective disease prevention programs. Additionally, the field evaluation of the interferon-gamma assay for tuberculosis diagnosis in Italy demonstrates the potential benefits of adopting standardized diagnostic criteria across different regions (Martucciello et al., 2020). Collaborative research and policy initiatives can facilitate the development of comprehensive disease management strategies, ensuring the health and productivity of water buffalo populations worldwide.

7 Concluding Remarks

The review of current control strategies for infectious diseases in water buffalo has highlighted several critical points. Firstly, parasitic infections such as those caused by *Neospora caninum* and *Toxoplasma gondii* are significant contributors to reproductive issues, including abortion and embryonic death, in water buffalo. Additionally, water buffaloes have shown a high resistance to reinfection with *Schistosoma japonicum*, primarily

due to acquired immunity, which is promising for future vaccine development. Tick-borne diseases, including those caused by *Anaplasma marginale*, *Babesia bovis*, and *Babesia bigemina*, are prevalent and pose a significant threat to buffalo health and productivity. Moreover, coccidiosis, caused by *Eimeria* species, remains a major cause of diarrhea in buffaloes, affecting their overall health and productivity. The presence of zoonotic diseases such as leptospirosis, brucellosis, and bovine tuberculosis further complicates the health management of water buffaloes, posing risks to both animal and human health.

Future research should focus on developing effective vaccines and treatment protocols for the most prevalent and impactful diseases affecting water buffalo. Specifically, there is a need for vaccines targeting *Neospora caninum* and *Toxoplasma gondii* to mitigate reproductive losses. Additionally, further studies on the immune response mechanisms in water buffalo, particularly concerning resistance to *Schistosoma japonicum*, could inform vaccine development and improve disease control strategies. Enhanced surveillance and molecular characterization of tick-borne pathogens are essential to understand their epidemiology and develop targeted control measures. Policies should also prioritize the implementation of comprehensive herd health management programs, including regular screening for zoonotic diseases and the adoption of biosecurity measures to prevent disease transmission between buffaloes and other livestock.

Improving the health and productivity of water buffalo requires a multifaceted approach that includes advancements in disease prevention, early diagnosis, and effective treatment strategies. Emphasizing the development of vaccines and enhancing biosecurity measures will be crucial in reducing the incidence of infectious diseases. Additionally, educating farmers on best practices for animal husbandry and disease management can significantly contribute to the overall health and productivity of water buffalo herds. By addressing both the economic and public health aspects of infectious diseases in water buffalo, we can ensure the sustainability and growth of this vital livestock sector.

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Conflict of Interest Disclosure

The authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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