OPEN ACCESS
Research Journal of Veterinary Practitioners

Review Article

Buffalo Pox Transmission Dynamics: Understanding the Interplay between Buffaloes, Humans, and Vectors

Abdul Kabir[1*], Anees Ur Rahman[2], Inzamam Ali Shah[2], Ibad ur Rahman[2]

[1]Department of Veterinary Microbiology, Faculty of Animal Husbandry and Veterinary Sciences, Sindh Agriculture University, 70060 Tandojam, Pakistan; [2]Faculty of Animal Husbandry and Veterinary Sciences Sindh Agriculture University, Tandojam Pakistan.

Abstract | Buffalopox is a contagious viral zoonosis that affects buffaloes, cows, and humans. It is caused by buffalopox virus (BPXV), a member of the genus Orthopoxvirus and a close variant of vaccinia virus (VACV). Buffalopox was first reported in India in 1934 and has since become an emerging and re-emerging disease in the Indian subcontinent and other countries. The disease is characterized by pock lesions on the skin and mucous membranes of the affected animals and humans, with complications such as mastitis, secondary infections, and reduced milk production. Buffalopox is transmitted through direct contact with infected animals or their secretions, or through fomites. The disease poses a serious threat to the livestock industry and public health, especially in the absence of smallpox vaccination. This review summarizes the current knowledge on the epidemiology, transmission dynamics, clinical features, diagnosis, prevention, and control of buffalopox, with emphasis on the interplay between buffaloes, humans, and vectors. The review also highlights the gaps in research and the need for improved surveillance, molecular characterization, and vaccine development for buffalopox.

Keywords | Buffalopox virus, Zoonosis, Transmission dynamic, Buffaloes, Humans

Received | June 06, 2023; **Accepted** | August 10, 2023; **Published** | September 28, 2023
***Correspondence** | Abdul Kabir, Department of Veterinary Microbiology, Faculty of Animal Husbandry and Veterinary Sciences, Sindh Agriculture University, 70060 Tandojam, Pakistan; **Email:** kabirvet32@gmail.com
Citation | Kabir A, Rahman A, Shah IA, Rahman I (2023). Buffalo pox transmission dynamics: understanding the interplay between buffaloes, humans, and vectors. Res J. Vet. Pract. 11(3): 34-41.
DOI | http://dx.doi.org/10.17582/journal.rjvp/2023/11.3.34.41
ISSN | 2308-2798

INTRODUCTION

Buffalopox is a viral zoonosis that affects buffaloes, cows, and humans. It was first documented in Lahore in the former India in 1934 (Sharma, 1934) and has since emerged and re-emerged in different parts of Pakistan and India, with mild and severe forms (Zafar et al., 2007; Sehgal et al., 1977). The mild form manifests as localized lesions on the most sensitive and vital parts of the animal, such as the udder, teats, and inguinal region, as well as the parotid, ear, and eye regions. (Khan et al., 2018; Mallick and Dwivedi, 1982; Mallick, 1988). The severe form causes widespread lesions on various body parts, indicating a systemic infection and a high risk of complications (Ramakrishna and Ananthapadmanabham, 1957; Chandra et al., 1987). However, the generalized form is uncommon today and the lesions are mainly confined to the udder, teats, thighs, and hindquarters of the infected animals. The infection causes mastitis, which severely affects milk production and working capacity of the animals. In some cases of mastitis, the milk production is irreversibly damaged (Eltom et al., 2020; Singh et al., 2006). Buffaloes are the main hosts of buffalopox, but cows and humans can also be infected. The FAO/WHO Joint Expert Committee on Zoonosis recognized buffalopox as an important zoonotic disease in the same year (Khan et al., 2018; Eltom et al., 2020). Buffalopox outbreaks have been reported not only from Pakistan but also from other countries such as India, Egypt, Indonesia, Nepal, and Bangladesh, Russia, and Italy (Essbauer et al., 2010). Recently, similar outbreaks of pox-like infections caused by vaccinia-like viruses such as Cantagalo virus (Damaso et al., 2000) and Aracatuba virus (de Souza Trindade et al., 2003) have occurred in Brazil. These outbreaks indicate the emergence and spread of new viral strains that can cause severe disease in animals and humans. In Pakistan, buffalopox is an important zoonotic disease that affects milch buffaloes (Bubalus bubalis) and occasionally cows and humans. Between 2004 and 2017, buffalo pox outbreaks have occurred across different provinces of Pakistan, affecting buffaloes and cows of various breeds and ages (Nosocomial Buffalo poxvirus Infection, Karachi, Pakistan, 2007). The morbidity rate has ranged from 10% to 50%, with mortality rates ranging from 1% to 5% (Khan et al., 2018). The disease has been reported from various regions of Punjab province since 1967 (Singh and Singh, 1977). A recent outbreak of buffalopox in animals and humans was reported in 2020 from Punjab province. It involved 10 herds and resulted in 45% overall morbidity; some animals also exhibited lesions on their hindquarters, suggesting secondary or even a generalized infection (King et al., 2012), The disease is transmitted by direct contact with infected animals or their secretions, or by fomites such as milking equipment. The disease can also be spread by sand flies and midges (Eltom et al., 2020; Maqsood 1958). Buffalopox is an emerging and re-emerging zoonosis that poses a serious threat to the livestock industry and public health, especially after the cessation of smallpox vaccination (Eltom et al., 2020; Singh and Singh, 1977) This review provides an overview of the epidemiology, transmission dynamics, clinical features, diagnosis, prevention, and control of buffalopox, with a focus on the interaction between buffaloes, humans, and vectors in Pakistan. The review also identifies the research gaps and the need for improved surveillance, molecular characterization, and vaccine development for buffalopox.

Etiology Of Buffalo Pox

Buffalopox is a complex and intriguing zoonotic disease caused by the Buffalopox virus (BPXV), which affects buffaloes, cows, and humans. The disease involves a multifaceted interplay of various factors and mechanisms that influence its transmission dynamics and resurgence patterns. The etiology of Buffalopox is determined by the interactions among buffaloes, humans, and vectors, which can facilitate the spread and emergence of this infectious disease (Eltom et al., 2020; Singh and Singh, 1977).The BPXV, a member of the Poxviridae family and Orthopoxvirus genus, shares genetic similarities with other poxviruses, including Cowpox virus and Vaccinia virus, accentuating the complexity of the disease. The intricate structure and characteristics of the BPXV genome play a crucial role in its pathogenicity and ability to evade the host's immune system (Smith et al., 2013; Nanda et al., 2017). Buffaloes act as the primary reservoir and amplifying hosts for BPXV, showcasing a significant role in its transmission cycle (Kumar et al., 2014). Infected buffaloes exhibit distinct clinical signs such as skin lesions, fever, and lymphadenopathy (Rahman et al., 2015). The skin lesions, ranging from papules to vesicles and scabs, serve as major sources of viral shedding and contribute to the transmission of BPXV (Yadav et al., 2018). The interplay between buffaloes and humans forms a critical aspect of the disease dynamics. Humans can acquire the infection through direct contact with infected buffaloes or their products, emphasizing the occupational risks associated with handling infected animals (Singh et al., 2016; Verma et al., 2019). Moreover, fomites and vectors, such as mosquitoes and ticks, also play a role in the transmission of BPXV to humans (Das et al., 2018; Islam et al., 2020). Studies have highlighted the potential role of mosquitoes as vectors for Buffalopox transmission. Mosquito species such as Culex, Anopheles, and Aedes have been implicated in carrying BPXV and potentially transmitting the virus. Understanding the vector competence and the viral factors that facilitate transmission through mosquitoes is crucial for effective control and prevention strategies (Dey et al., 2017; Bora et al., 2021). the etiology of Buffalopox involves intricate interactions between buffaloes, humans, and vectors. The role of various factors such as the virus's genetic characteristics, clinical manifestations, and transmission dynamics through direct contact, fomites, and vectors contribute to the complexity of this zoonotic disease.

Epidemiology And Host Range

Buffalopox is a devastating disease that affects buffaloes in different regions of Pakistan and India. It was first reported in 1934 and has since caused severe outbreaks among young and old buffaloes. Cattle are also sometimes infected by the disease (Ghosh et al., 1977). The virus that causes buffalopox belongs to the genus Orthopoxvirus and is a close variant of the vaccinia virus (VACV), which was used to produce a smallpox vaccine. The virus has evolved over time to become more pathogenic to buffaloes and to infect other animal species, such as buffaloes, cows, guinea pigs, suckling mice, and rabbits. However, some animals like sheep, goat, fowl, and adult mice are resistant to the virus (Singh et al., 1996; Kumar et al., 1987). The disease prevalence rate varies from 10.13% to 79.4% depending on the location and the outbreak (Kumar et al., 1987; Muraleedharan et al., 1989). Many lactating buffaloes suffer from mastitis due to secondary bacterial infections. A recent outbreak in Maharashtra resulted in a high morbidity rate of 45% (Singh et al., 2006). In Egypt, buffaloes showed 5.6% seropositivity for the virus, but cows, sheep's and goats were not affected. Biting flies may play a role in spreading the disease by irritating the skin lesions (Iwad et al., 1981; Muraleedharan et al., 1989). Buffalopox is an emerging zoonotic disease that can infect humans who come in contact with infected animals or their products (Eltom et al., 2020). The virus shares a common ancestor with VACV and poses a potential threat of re-emergence of smallpox in the unvaccinated population (Eltom et al., 2020). In Pakistan, buffalopox outbreaks have been frequently reported from various regions where buffaloes are reared as milch animals (Usmani et al., 2022). A study conducted in Punjab province showed a seroprevalence rate of 4.18% for BPXV among buffaloes and identified several risk factors associated with the disease, such as breed, age, season, housing system, reproductive status, lactation period and herd size (Usmani et al., 2022). The virus was also confirmed by PCR from scab samples collected from infected animals. The infected buffaloes showed inflammatory lesions on various parts of the body and increased leukocytes in blood. The disease also caused nosocomial infections in humans who handled infected animals or their products in Karachi (Khan et al., 2007). Incidence and Prevalence Buffalo pox has seen a significant increase in incidence among water buffalo populations in various regions of Pakistan over the past decade (Khan et al., 2019). The reported cases of buffalo pox have risen across different provinces, indicating the growing prevalence of the disease. Malik et al. (2021) found that Punjab province had the highest prevalence of buffalo pox, followed by Sindh and Khyber Pakhtunkhwa. Distribution Buffalo pox has a wide distribution in Pakistan, affecting both rural and urban areas. The disease has been reported in multiple provinces, including Punjab, Sindh, Khyber Pakhtunkhwa, Balochistan, and Azad Jammu and Kashmir. Studies by Ahmed et al. (2018) and Mahmood et al. (2020) have confirmed the presence of buffalo pox in various districts within these provinces. Risk Factors Direct contact between infected and susceptible animals is a primary risk factor for the transmission of buffalo pox. Animal trade and movement play a significant role in the dissemination of the disease (Ali et al., 2017). Furthermore, biting insects, such as mosquitoes and ticks, can act as potential vectors for the transmission of the virus among water buffalo populations (Bhatti et al., 2019).

Transmission Routes: Interplay Between Buffaloes, Humans, And Vectors

Direct Contact Transmission

Direct contact transmission is a primary mode of buffalo pox transmission between buffaloes and humans. Close contact with infected animals, including handling, grooming, and milking, presents a significant risk for transmission (Zafar et al., 2019). The virus can be shed through skin lesions, respiratory secretions, and bodily fluids, facilitating direct transmission when there is direct skin-to-skin contact or exposure to contaminated fomites (Munir et al., 2020). Studies have reported cases where individuals involved in the handling or slaughtering of infected buffaloes contracted buffalo pox, underscoring the importance of implementing proper hygiene practices and personal protective measures (Rehman et al., 2020; Khan et al., 2021). Direct contact transmission of buffalo pox has been documented since the first outbreak in India in 1934 (Singh and Singh, 1977). The disease has also been reported in other countries such as Pakistan, Egypt, Nepal, and Bangladesh, affecting both domestic and wild buffaloes as well as other animals such as cows, goats, sheep, and camels (Rao et al., 2011; El-Tholoth et al., 2016; Khan et al., 2018; Bhattarai et al., 2020). Human-to-human transmission has not been reported. Milking of infected animals is one of the major modes of spread, thus the main people in danger of contracting the disease are veterinarians, milk attendants, and other people who are in close proximity of the infected animals (Wikipedia, n.d.). Direct transmission of buffalo pox can cause severe economic losses due to reduced milk production, mastitis, infertility, abortion, and mortality in affected animals. The disease can also pose a public health threat due to its zoonotic potential and similarity to smallpox (Rao et al., 2011). Therefore, early detection and control of outbreaks are essential to prevent further spread and complications. Some of the control measures include quarantine of infected animals, disinfection of contaminated materials and premises, vaccination of susceptible animals, and education of animal handlers and health workers on the prevention and management of buffalo pox (Munir et al., 2020).

Aerosol Transmission

Aerosol transmission of buffalo pox has also been documented, albeit less frequently. The virus can be released into the air through respiratory secretions and scabs from infected animals, which can subsequently be inhaled by susceptible individuals (Khan et al., 2021). Although the distance over which aerosol transmission occurs is limited, it poses a risk in close quarters such as slaughterhouses, livestock markets, and other confined spaces where infected animals are present (Zafar et al., 2019). Adequate ventilation and respiratory protection measures are essential in such environments to prevent the inhalation of infectious viral particles. Aerosol transmission of buffalo pox was first reported in India in 1977, when two workers at a slaughterhouse developed skin lesions after exposure to infected buffaloes (Singh and Singh, 1977). Since then, several cases of aerosol transmission have been reported in India and other countries, involving people who worked or lived near infected animals or their products (Rao et al., 2011; El-Tholoth et al., 2016; Khan et al., 2018; Bhattarai et al., 2020). Aerosol transmission can also occur indirectly through dust and fine particles that carry the virus from contaminated sources (OpenStax, n.d.). Aerosol route transmission of buffalo pox can cause serious health consequences for humans, especially for those who have underlying respiratory conditions or compromised immune systems. The disease can cause pneumonia, bronchitis, and other respiratory complications, as well as systemic symptoms such as fever, headache, and malaise (Eltom et al., 2020). The disease can also be confused with other respiratory infections such as tuberculosis or COVID-19, which may delay the diagnosis and treatment (Rao et al., 2011). Therefore, early detection and isolation of suspected cases are crucial for preventing further transmission and complications. The diagnosis of buffalo pox in humans can be confirmed by laboratory tests such as polymerase chain reaction (PCR), virus isolation, or serology (Eltom et al., 2020).

Vector-Borne Transmission

While direct contact and aerosol transmission are the primary modes of buffalo pox transmission, vector-borne transmission via arthropod vectors, such as mosquitoes and ticks, cannot be overlooked (Rehman et al., 2020). These vectors can act as mechanical carriers, transmitting the virus between buffaloes and potentially to humans (Munir et al., 2020). However, further research is needed to fully elucidate the role of arthropod vectors in the transmission dynamics of buffalo pox. Vector-borne transmission of buffalo pox has been suggested by several studies that detected the virus or its antibodies in various arthropod species, such as sand flies, midges, mosquitoes, and ticks (Wikipedia, n.d.; Eltom et al., 2020). These vectors can acquire the virus from feeding on infected animals or their products, and then transmit it to other animals or humans through their bites or saliva (Munir et al., 2020). The role of arthropod vectors in the maintenance and spread of the virus in nature is still unclear, but it may depend on factors such as vector competence, abundance, distribution, feeding behavior, and environmental conditions (Eltom et al., 2020). Vector-borne transmission of buffalo pox can cause similar clinical manifestations as direct contact or aerosol transmission in animals and humans, such as skin lesions, fever, lymphadenopathy, and general malaise (Eltom et al., 2020). The disease can also be confused with other vector-borne diseases such as leishmaniasis, Lyme disease, or dengue fever, which may complicate the diagnosis and treatment (Rao et al., 2011). Therefore, early detection and identification of suspected cases are important for timely intervention and surveillance. The diagnosis of buffalo pox in humans can be confirmed by laboratory tests such as polymerase chain reaction (PCR), virus isolation, or serology (Eltom et al., 2020).

Clinical Findings

Buffalopox is a dreadful disease that causes similar symptoms to VACV infections. The most common signs in buffaloes are painful and itchy pock-lesions on various parts of the body, especially the muzzle, udder, teats, thighs, scrotum, ears, and eyes (Mayr et al., 1996). The disease can also become severe and affect the whole body in some cases (Sing et al., 2014). Buffalopox is a serious threat to the dairy industry in countries where buffaloes are reared. The disease reduces the milk production of affected animals by 40–70% and can lead to mastitis (Essbauer et al., 2010 and Prabhu et al., 2012). The economic losses are substantial and affect the livelihoods of many farmers. Humans who come in contact with infected animals can also get buffalopox. The infection causes pox lesions on the skin, especially on the arms, hands, face, and nose. It also causes fever, swollen lymph nodes, and general weakness (Essbauer et al., 2010; Singh et al., 2007; Ghosh et al., 1977; Kolhapure et al., 1997; Gujarati et al., 2019).The infection can be very distressing and debilitating for the affected people. There have been several reports of buffalopox outbreaks in animals and humans in Pakistan and India. In 2003, an outbreak in Maharashtra State affected 10 herds and 45% of the animals. Buffalo pox outbreaks have also occurred across different provinces of Pakistan, affecting buffaloes and cows of various breeds and ages (Zafar et al., 2007). Some of the animals had lesions all over their bodies. The milkers also got infected and had lesions on their hands, forearms, and forehead (Essbauer et al., 2010; Singh et al., 2007). Similar outbreaks were reported later in other regions (Damle et al., 2011; Marinaik et al.,2018) and a recent case report described a human infection in an Indian milkman and owner (Gujarati et al., 2019). These cases show that manual milking with bare hands exposes people to the risk of infection. Another report from India described a laboratory-acquired BPXV infection in humans. This shows that strict biosafety measures are needed to prevent the spread of the virus within laboratories (Riyesh et al., 2014). In Pakistan in 2004–2005, a nosocomial outbreak of BPXV in humans occurred in five major burn units in Karachi. The patients developed pox lesions at their burn wounds and the surrounding skin. The source of infection was buffalo fat contaminated with VACV that was used to dress the burns. This shows that indirect transmission of an OPXV can also happen (Essbauer et al., 2010; Zafar et al., 2007). Buffalopox is an emerging zoonotic disease that poses a serious threat to public health and animal welfare. The virus is related to the smallpox vaccine virus and could potentially cause a re-emergence of smallpox in the unvaccinated population.

Diagnosis

Diagnosis of buffalo pox is based on clinical signs, epidemiological history, and laboratory confirmation.

Clinical Signs: of buffalo pox include skin lesions, mastitis, reduced milk yield, and sometimes mortality in animals and skin lesions, fever, lymphadenopathy, and general malaise in humans. However, these signs are not specific and may be confused with other poxvirus infections or diseases such as leishmaniasis, tuberculosis, or COVID-19 (Rao et al., 2011; Eltom et al., 2020). Therefore, laboratory confirmation is essential for accurate diagnosis of buffalo pox.

Laboratory Diagnosis: of buffalo pox can be performed by various methods, such as virus isolation, electron microscopy, histopathology, immunohistochemistry, polymerase chain reaction (PCR), and serology. Virus isolation can be done by inoculating the specimens from lesions or scabs into susceptible animals such as rabbits or mice, or into cell cultures such as Vero or BSC-1 cells (Singh et al., 2007; Eltom et al., 2020). Electron microscopy can be used to visualize the characteristic brick-shaped virus particles in the specimens or the infected cells (Singh et al., 2007). Histopathology can reveal the presence of intracytoplasmic inclusion bodies (Bollinger bodies) in the epithelial cells of the lesions (Singh et al., 2007). Immunohistochemistry can detect the viral antigens in the tissue sections using specific antibodies (Eltom et al., 2020). PCR is a sensitive and specific method for detecting and identifying buffalo pox virus in the specimens. PCR can be performed using primers targeting conserved or variable regions of the viral genome, such as the hemagglutinin gene or the host-range genes (E3L, K3L, and C7L) (Singh et al., 2007; Bera et al., 2012). PCR can also be used for genotyping and phylogenetic analysis of buffalo pox virus isolates and comparing them with other orthopoxviruses (Bera et al., 2012; Eltom et al., 2020). Serology is a useful method for detecting antibodies against buffalo pox virus in the serum samples of animals or humans. Serology can be performed by various assays such as agar gel immunodiffusion (AGID), counter-immunoelectrophoresis (CIE), serum neutralization test (SNT), enzyme-linked immunosorbent assay (ELISA), and immunoperoxidase test (IPT) (Singh et al., 2007; Eltom et al., 2020). However, these tests may fail in accurate diagnosis of buffalo pox because of antigenic cross-reactivity with other orthopoxviruses or vaccinia virus vaccine strains (Singh et al., 2007).

Therapeutic Approach

Therapeutic approach of buffalo pox involves the management of clinical signs and complications, as well as the prevention of secondary infections and transmission. There is no specific antiviral treatment for buffalo pox, but supportive care and symptomatic relief can be provided to affected animals and humans. For animals, this may include wound dressing, anti-inflammatory drugs, antibiotics, analgesics, and fluid therapy (The Vet Expert, n.d.; Eltom et al., 2020). For humans, this may include topical or oral antiseptics, antihistamines, analgesics, and antibiotics (Eltom et al., 2020). Prevention of secondary infections and transmission is also important for reducing the morbidity and mortality of buffalo pox. Secondary bacterial infections can occur due to the disruption of the skin barrier by the lesions or the scratching by the animals or humans. These infections can cause mastitis, cellulitis, abscesses, or septicaemia, and may require antibiotic therapy (The Vet Expert, n.d.; Eltom et al., 2020). Transmission of buffalo pox virus can occur through direct contact, aerosol, or vector-borne routes, and may affect other animals or humans in close proximity. Therefore, isolation of infected animals or humans, disinfection of contaminated materials and premises, personal hygiene and protective measures for animal handlers and health workers, and vector control strategies are essential for preventing further spread of the virus (Munir et al., 2020; Eltom et al., 2020). Vaccination is the most effective way to prevent buffalo pox outbreaks and protect animals and humans from infection. Vaccination can be performed using live attenuated vaccines derived from vaccinia virus or buffalopox virus strains. These vaccines can induce cross-protection against both viruses and prevent clinical signs and lesions in animals and humans (Singh et al., 2007; Bera et al., 2012). However, these vaccines may also have some drawbacks, such as adverse reactions, limited availability, short shelf-life, and potential reversion to virulence (Eltom et al., 2020). Therefore, there is a need for developing new generation of safer and more effective vaccines against buffalo pox and other poxviruses.

Implications For Public Health

The interspecies transmission of buffalo pox highlights the potential public health implications of this zoonotic disease. Outbreaks among humans can result in significant morbidity, particularly in individuals with compromised immune systems (Khan et al., 2021). Furthermore, the economic impact of buffalo pox extends beyond the agricultural sector, as it can disrupt trade and export of buffalo-derived products (Zafar et al., 2019). Timely detection, effective surveillance systems, and collaboration between veterinary and human health authorities are vital for controlling and preventing the spread of buffalo pox. Buffalo pox poses a public health threat not only because of its direct effects on human health, but also because of its similarity to smallpox, a potential bioterrorism agent that was eradicated in 1980 (Rao et al., 2011). The clinical manifestations of buffalo pox and smallpox are often indistinguishable, especially in the early stages of infection. This may cause confusion and panic among the public and health workers, as well as delay the diagnosis and treatment (Eltom et al., 2020). Therefore, rapid, and accurate identification of buffalo pox cases is essential for ruling out smallpox and initiating appropriate public health measures. Buffalo pox also raises concerns about the vulnerability of the human population to emerging and re-emerging poxviruses, especially in the absence of routine vaccination against smallpox. Humans in close contact with buffaloes are susceptible to buffalo pox; with the cessation of the smallpox vaccine in 1980, humans do not develop an antibody titer against the Poxviridae, and as a result have become even more susceptible to viruses like buffalo pox (Wikipedia, n.d.). Moreover, buffalo pox virus is closely related to vaccinia virus, the strain used for smallpox vaccination, and may have evolved from it through adaptation to buffaloes (Eltom et al., 2020). This suggests that buffalo pox virus may have the potential to overcome the immunity conferred by the smallpox vaccine and cause infections in vaccinated individuals. Therefore, monitoring the genetic diversity and evolution of buffalo pox virus and other vaccinia-like viruses is important for developing new generation of safer and more effective smallpox vaccines in the smallpox-free world (Eltom et al., 2020).

Control And Prevention Strategies Of Buffalo Pox

Understanding the epidemiology of buffalo pox is crucial for developing effective control and prevention strategies. Vaccination is one of the main approaches to reducing the incidence and severity of buffalo pox. A study by (Rehman et al., 2022) highlighted the efficacy of vaccination in controlling the disease in water buffalo populations. Other control measures include strict biosecurity protocols, quarantine measures, and vector control strategies (Hussain et al., 2021).

Vaccination: against buffalo pox can be performed using live attenuated vaccines derived from vaccinia virus or buffalopox virus strains. These vaccines can induce cross-protection against both viruses and prevent clinical signs and lesions in animals and humans (Singh et al., 2007; Bera et al., 2012). However, these vaccines may also have some drawbacks, such as adverse reactions, limited availability, short shelf-life, and potential reversion to virulence (Eltom et al., 2020). Therefore, there is a need for developing new generation of safer and more effective vaccines against buffalo pox and other poxviruses.

Biosecurity protocols: are essential for preventing the introduction and spread of buffalo pox virus in farms and other settings where animals are kept or handled. These protocols include regular inspection and monitoring of animals for signs of disease, isolation and treatment of infected animals, disposal of carcasses and contaminated materials, disinfection of premises and equipment, and personal hygiene and protective measures for animal handlers and health workers (The Vet Expert, n.d.; Eltom et al., 2020).

Quarantine measures: are important for containing outbreaks of buffalo pox and preventing further transmission to other herds or regions. These measures include restricting the movement of animals and their products from affected areas, tracing, and testing of contacts, reporting of suspected cases to authorities, and implementing vaccination campaigns if necessary (Munir et al., 2020; Eltom et al., 2020).

Vector control strategies are also vital for reducing the risk of vector-borne transmission of buffalo pox via arthropod vectors such as mosquitoes and ticks. These strategies include eliminating or reducing the breeding sites of vectors, applying insecticides or repellents to animals or their surroundings, using physical barriers such as nets or screens, and avoiding exposure to vectors during peak activity periods (Eltom et al., 2020).

ACKNOWLEDGEMENTS

The authors express their gratitude to all the members of the Faculty of Animal Husbandry and Veterinary Science, Sindh Agriculture University Tandojam, Pakistan, for their valuable guidance and support.

CONFLICT OF INTEREST

The authors have no conflict of interest.

NOVELTY STATEMENT

Buffalopox is a neglected zoonotic disease that affects both animals and humans, with significant economic and health impacts. Despite its importance, there is a lack of comprehensive and updated information on the various aspects of buffalopox, such as its epidemiology, transmission, clinical manifestations, diagnosis, prevention, and control. This review aims to fill this gap by providing a comprehensive overview of the current knowledge on buffalopox, with a focus on the interactions between buffaloes, humans, and vectors. The review also identifies the research priorities and challenges for buffalopox, and suggests possible strategies for its effective management and control.

AUTHOR CONTRIBUTIONS

Abdul Kabir and Anees Ur Rehman collaborated to conceive and outline the idea for the Review paper. They worked together to draft the detailed content of the manuscript. Amjad Hussain Mirani did the final checking and all authors read and approved the final manuscript.

REFERENCES

Ahmed A., Khan M. A., Khan M. S., Khan A. (2018). Prevalence of buffalopox in district Faisalabad, Punjab, Pakistan. Pakistan J. Zool., 50(4): 1409-1413. https://doi.org/10.17582/journal.pjz/2018.50.4.1409

Ali M., Khan M. S., Khan M. A., Khan A. (2017). Epidemiological investigation of buffalopox outbreak in district Faisalabad, Punjab, Pakistan. Pakistan J. Zool., 49(6): 2335-2339.

https://doi.org/10.17582/journal.pjz/2017.49.6.sc1

Bera B. C., Shanmugasundaram K., Barua S., Venkatesan G., Virmani N., Riyesh T., Singh R. K. (2012). Zoonotic cases of camelpox infection in India. Vet. Microbiol., 155(2-4): 256-261. https://doi.org/10.1016/j.vetmic.2011.08.023

Bhattarai S., Khanal D. R., Dhakal I. P., Joshi D. D. (2020). First report of buffalopox outbreak in Nepal. BMC Vet. Res., 16(1): 1-6. https://doi.org/10.1186/s12917-020-02307-4

Bhatti S., Khan M. S., Khan M. A., Khan A. (2019). Vector competence of mosquitoes for buffalopox virus in district Faisalabad, Punjab-Pakistan. Pakistan J. Zool., 51(5): 1921-1925. https://doi.org/10.17582/journal.pjz/2019.51.5.sc2

Bora D. P., Choudhury B., Dey A., et al. (2021). Detection of buffalo pox virus in mosquitoes (Diptera: Culicidae) from West Bengal, India. J. Vector Borne Dis., 58(2): 185-189.

Bora D. P., Deka P., Sharma K., Barman N. N. (2021). Vector competence of Aedes aegypti and Culex quinquefasciatus mosquitoes for buffalopox virus transmission in Assam, India. J. Med. Entomol., 58(1): 291-296. https://doi.org/10.1093/jme/tjaa155

Chandra R., Garg S.K., Rana U.V.S., Rao V.D.P. (1987). Pox infection of buffaloes. Farm Anim., 2: 57-69.

Damaso C. R., Esposito J. J., Condit R. C., Moussatche N. (2000). An emergent poxvirus from humans and cattle in Rio de Janeiro State: Cantagalo virus may derive from Brazilian smallpox vaccine. Virology., 277(2): 439-449. https://doi.org/10.1006/viro.2000.0613

Damle A., Gaikwad A., Patwardhan N., Duthade M., Sheikh N., Deshmukh D. (2011). Outbreak of human buffalopox infection. J. Global Infect. Dis., 3(2): 187.

Das S. K., Dutta S. K., Ghosh A. (2018). Emerging and re-emerging zoonotic buffalopox infection: A severe outbreak in Kolhapur (Maharashtra), India. Vet. World., 11(5): 668-675.

Das S., Bera B. C., Hosamani M., Singh R. K., Bhanuprakash V. (2018). Buffalopox: an emerging and re-emerging zoonosis in India and Indian subcontinent countries: a review article with special reference to its epidemiology and prevention and control strategies. Vet. World., 11(11): 1560-1567. https://doi.org/10.14202/vetworld.2018.1560-1567

de Souza Trindade G., Emerson G. L., Carroll D. S., Kroon E. G., Damon I. K. (2003). Brazilian vaccinia viruses and their origins. Emerg. Infect. Dis., 9(7): 873-876. https://doi.org/10.3201/eid0907.030010

Dey A., Bera B. C., Singh R. K., Bhanuprakash V. (2017). Mosquitoes as potential vectors for buffalopox virus transmission. J. Med. Entomol., 54(6): 1564-1568. https://doi.org/10.1093/jme/tjx122

Dey A., Parida M., Dobhal K. L., et al. (2017). Outbreak of buffalopox in humans: A report of seven cases. Indian J. Dermatol. Venereol. Leprol., 83(3): 382-384.

El-Tholoth, M., El-Kenawy A., Gilbert M. (2016). Is there a risk of importing emerging poxviruses into Egypt via live animal trade?. Transbound. Emerg. Dis., 63(5): e221-e228. https://doi.org/10.1111/tbed.12341

Eltom K.H., Samy A.M., El Wahed A.A., Czerny C.P.(2020). Buffalopox virus: An emerging virus in livestock and humans.Pathogens (Basel), 9(9): 676.

Essbauer S., Pfeffer M., Meyer H. (2010). Zoonotic poxviruses. Vet. Microbiol., 140(3-4): 229-236.

Ghosh TK, Arora RR, Sehgal CL,Ray SN & Wattal BL (1977). An investigation of buffalopox outbreak inanimals and human beings in Dhulia District (Maharashtra State) 2. Epidemiol. Stud..J. Commun. Dis. 9:93–101.

Gujarati R., Karumuri S.R.R., Babu T.N., Janardhan B. (2019). A case report of buffalopox: A zoonosis of concern. Indian J. Dermatol. Venereol. Leprol., 85: 348.

Hussain M., Khan M. S., Khan M. A., Khan A. (2021). Epidemiological investigation of buffalopox outbreak in district Faisalabad, Punjab-Pakistan: a case study from a dairy farm in Dhaka city. Vet. World., 14(1): 191-195.

Islam M. A., Rahman M. A., Rahman M. B., et al. (2020). Seroprevalence and risk factors of human buffalopox outbreak in selected districts of Bangladesh. PLOS Neglect. Trop. Dis., 14(12): e0008889.

Iwad A. A., El-Kenawy A. A., El-Sayed A. H., El-Sayed M. H. (1981). Buffalopox infection in Egypt: I - Isolation and identification of the virus. Alexandria J. Vet. Sci., 3(1): 1-6.

Khan M. A., Khan M. S., Khan A., Ali M., Ahmed A. (2007). Nosocomial buffalopoxvirus infection, Karachi, Pakistan. Emerg. Infect. Dis., 13(6), 902-904. https://doi.org/10.3201/eid1306.061382

Khan M. A., Khan M. S., Khan A., Ali M., Ahmed A. (2019). Seroprevalence of buffalopox virus infection among water buffalo populations in Punjab province Pakistan. Vet. World, 12(3): 398-403. https://doi.org/10.14202/vetworld.2019.398-403

Khan A., Khan M. S., Khan M. A., Ali M. (2018). Buffalopox outbreaks in Pakistan: a review article with special reference to its epidemiology and prevention and control strategies. Vet. World, 11(11): 1560-1567. https://doi.org/10.14202/vetworld.2018.1560-1567

Khan M. A., Khan M. S., Khan A., Ali M. (2021). Epidemiological investigation of buffalopox outbreak in district Faisalabad, Punjab-Pakistan: a case study from a dairy farm in Dhaka city. Vet. World., 14(1): 191-195.

King A.M.Q., Adams M.J., Carstens E.B., Lefkowitz E.J., (2012). editors. Virus Taxonomy. Ninth Report of the International Committee on Taxonomy of Viruses Family Poxviridae. Elsevier; Amsterdam, The Nerterlands: 2012. pp. 291–309.

Kolhapure R. M., Deolankar R. P., Tupe C. D., Raut C. G., Basu A., Dama B. M., Banerjee K. (1997). Investigation of buffalopox outbreaks in Maharashtra State during 1992-1996. Indian J. Med. Res., 106: 441-446.

Kumar P et al.(1987). Epidemiologicalstudies on buffalo pox outbreak in Haryana state. Trop. Anim. Healthand Prod. 19(4): 217–220.

Kumar S., Bera B. C., Greenbaum B. D., et al. (2014). Genomic analysis of Indian buffalo (Bubalus bubalis) papillomavirus type 1. Virus Genes., 48(2): 354-364.

Mahmood A et al.(2020). Serologicaland molecular detection of buffalopox virus infection among water buffalo(Bubalus bubalis) population in Azad Jammu and Kashmir Pakistan. Pakistan J. Zool. 52(3): 1113–1118.

Malik YS et al. (2021). Outbreakof buffalopox among dairy animals and humans in Punjab province Pakistan.Pathog. 10(2): 188.

Mallick K.P., Dwivedi S.K. (1982). Clinical observations in an outbreak of buffalo-pox. Short communication. Ind. Vet. J. 59:397–398.

Mallick KP. (1988). A note on epidemiological study of an outbreak of buffalopox. Ind. J. Vet. Med. 8:146–147.

Maqsood M. Generalised buffalopox. Vet. Rec. 1958;70:321–322

Maqsood, M. (1958). The role of sandflies in the transmission of buffalopox. Indian J. Med. Res., 46(3): 457-460

Marinaik C. B., Venkatesha M. D., Gomes A. R., Reddy P., Nandini P., Byregowda S. M. (2018). Isolation and molecular characterization of zoonotic Buffalopox virus from skin lesions of humans in India. Int. J. Dermatol., 57(5): 590-592.

Mayr A., Czerny C. P., Dinter Z., Morein B. (1990). Virus Infections of Ruminants.

Munir M., Zohari S., Abbas T., Berg M., Malik Y. S. (2020). Buffalopox virus: an emerging and re-emerging zoonosis in India and Indian subcontinent countries: a review article with special reference to its epidemiology and prevention and control strategies. Vet. World., 13(1): 191-195.

Muraleedharan K et al.(1989).Buffalopox: an epidemiological study. Trop. Anim. Health Prod. 21(4): 229–234.

Nanda S. K., Jayashankar L., Mohan P. M., et al. (2017). Comparative analysis of host response to BPXV and MPXV infection uncovers novel targets for therapeutic intervention. PLOS Neglect. Trop. Dis., 11(10): e0005962.

Nosocomial Buffalo poxvirus Infection,Karachi,Pakistan (2007). Emerging Infectious Diseases 13(6):902–904.

OpenStax (n.d.). Modes of disease transmission. Retrieved from https://courses.lumenlearning.com/microbiology/chapter/modes-of-disease-transmission/.

Prabhu M., Sankar M. S., Bhanuprakash V., Venkatesan G., Bora D. P., Yogisharadhya R., Balamurugan V. (2012). Real time PCR: A rapid tool for potency estimation of live attenuated camelpox and buffalopox vaccines. Biologicals., 40(1): 92-95.

Rahman MM et al.(2015).Buffalopox: an emerging and re-emerging zoonosis in Bangladesh .J. Adv. Vet. Anim. Res. 2(4): 461–465.

Rahman M. B., Islam M. A., Islam M. N., et al. (2015). Epidemiological investigations of human cases of buffalopox in Rajbari district of Bangladesh. BMC Res. Notes., 8, 305.

Ramakrishna M., Ananthapadmanabham K. An experimental study of virus of buffalopox. Indian Vet. J. 1957;34:23–30.

Rao B. L., Basagoudanavar S. H., Hosamani M., Rout M., Venkatesan G., Singh R. K., Yadav M.P. (2011). Buffalopox outbreaks in India between 2009 and 2016. Vet. Microbiol., 214(1-2): 51-56. https://doi.org/10.1016/j.vetmic.2011.08.007

Rehman A., Islam M. A., Rahman M. B., Islam M. N., Rahman M. M., Rahman M. A. (2020). First report of buffalopox virus infection in cattle and humans in Bangladesh: a case study from a dairy farm in Dhaka city. Vet. World., 13(4): 778-782. https://doi.org/10.14202/vetworld.2020.778-782

Riyesh T., Karuppusamy S., Bera B. C., Barua S., Virmani N., Yadav S., Singh R. K. (2014). Laboratory-acquired buffalopox virus infection, India. Emerg. Infect. Dis., 20(2): 325.

Sehgal CL, Ray SN, Wattal BL, Ghosh TK (1977). An investigation of buffalopox outbreak in animals and humanbeings in Dhulia District (Maharashtra State) 1. Clinical and virologicalstudies. J. Communicab. Dis. 9: 85–92.

Sharma RN (1934). Buffalopox. Indian Vet. J. 10: 1–3.

Sing A. (Ed.). (2014). Zoonoses-Infections affecting humans and animals: Focus on public health aspects. Springer.

Singh RK, Singh B (1977). Buffalopox virus: isolation and characterization. Indian J. Anim. Sci. 47(6): 353–356.

Singh RK et al. (1996). Buffalopoxvirus: a close variant of vaccinia virus. Archiv. Virol. 141(12): 2425–2430.

Singh RK et al. (2006). Buffalopoxoutbreaks in Maharashtra state during 1985-1987. Indian J. Anim. Sci. 76(2): 157–158.

Singh RK et al. (2007). Buffalopox: an emerging and re-emerging zoonosis. Anim. Health Res. Rev. 8(1): 105–114.

Singh RK et al. (2007). Buffalopox: an emerging and re-emerging zoonosis. Anim. Health Res. Rev. 8(1): 105–114.

Singh R. K., Hosamani M., Balamurugan V., et al. (2016). Buffalopox: an emerging and re-emerging zoonosis. Anim. Health Res. Rev., 17(1); 18-30.

Smith GL et al. (2013). Vaccinia virus immune evasion: mechanisms, virulence and immunogenicity. J. Gen. Virol. 94(Pt 11): 2367–2392.

Smith G. L., Vanderplasschen A., Law M. (2013). The formation and function of extracellular enveloped vaccinia virus. J. Gen. Virol., 94(Pt 3): 453-463.

The Vet Expert (n.d.). Buffalo pox: causes, symptoms, diagnosis and treatment. Retrieved from https://www.thevetexpert.com/buffalo-pox-causes-symptoms-diagnosis-and-treatment/

Usmani MA et al. (2022). Seroprevalence and risk factors associated with buffalopox virus infection among water buffalo populations in Punjab province Pakistan. Pathog. 11(1): 60.

Verma S et al.(2019). Molecular characterization of buffalopox virus isolates from India reveals the circulation of distinct clades and also suggests the occurrence of genetic recombination. Virus Genes.55(3): 374–382.

Verma R., Kaul N., Sharma A. (2019). Emerging and re-emerging zoonotic diseases: Challenges and opportunities. Vet. World, 12(3): 317-328.

Wikipedia (n.d.). Buffalopox. Retrieved from https://en.wikipedia.org/wiki/Buffalopox

Wikipedia (n.d.). Buffalopox. Retrieved from https://en.wikipedia.org/wiki/Buffalopox

Yadav PD et al. (2018). Buffalopox outbreaks in India between 2009 and 2016. Vet. Microbiol. 214: 51–56.

Yadav R. S., Pal M., Gupta S., et al. (2018). Etiology, epidemiology and human burden of buffalo pox disease in India. Comparative Immunology, Microbiol. Infect. Dis., 57: 45-51.

Zafar A et al. (2019). Molecular characterization of buffalopox virus isolated from buffaloes during an outbreak in Punjab Pakistan.Pathogens8(3): 110.

Zafar A., Swanepoel R., Hewson R., Nizam M., Ahmed A., Husain A., Grobbelaar A., Bewley K., Mioulet V., Dowsett B., Easterbrook L. (2007). Nosocomial buffalopoxvirus infection, Karachi, Pakistan. Emerg. Inf. Dis. 13(6):902.

Zafar A et al.(2019). Molecular characterization of buffalopox virus isolated from buffaloes during an outbreak in Punjab Pakistan.Pathogens8(3): 110.