

Vector-Borne Zoonotic Disease Outbreaks and Public Health: Emerging Threats and Solutions

AUTHORS DETAIL

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Abstract

The analysis of vector-borne zoonotic diseases, highlighting their public health impact, transmission mechanisms, and the essential control strategies required to mitigate their effects. As global mobility and ecological disruption enhance the transmission capabilities of these diseases, there is a growing imperative to understand their dynamics and implement effective public health interventions. Zoonotic diseases can categorize into viral, bacterial, rickettsial, and parasitic diseases because each associated with specific vectors and transmission routes. This chapter emphasizes a One Health approach by advocating for integrated health strategies that encapsulate human, animal, and environmental health spheres to combat zoonotic diseases effectively. Moreover, it extends to practical measures such as vaccination, surveillance, and inter-sectoral cooperation, which are crucial for preventing outbreaks and managing public health threats efficiently. This chapter not only educates on the various aspects of zoonotic diseases but also calls for enhanced global cooperation to address these pervasive health challenges.

Keywords: Vector-borne diseases, Zoonotic diseases, Public health, Emerging threats, Disease prevention

Introduction

The spread of zoonotic diseases, or diseases that are infective and transferred between animal hosts and human hosts, pose a threat to global health. These diseases are caused by a variety of pathogens including viruses, bacteria, parasites and fungi, all of which impact the health of humans and animals. More than 300 zoonotic illnesses are currently being reported from both developed and developing countries worldwide (Rahman et al., 2020).

The interface between diverse animal hosts, humans, and environmental factors facilitates the spread of these diseases, often leading to significant public health crises and economic disruptions, particularly in developing regions. Over 300 zoonoses have been recognized, with new ones continually emerging, like Kyasanur Forest Disease (KFD) and Monkeypox, highlighting

the urgent need for effective surveillance and management strategies., mitigating their effects on public health (Keshavamurthy & Charles, 2023).

Four categories of zoonosis.

Direct Zoonoses: Transmitted directly from an infected vertebrate host to another susceptible vertebrate without the need for an intermediate vector or any change in the lifecycle of the infectious agent. Transmission can occur through direct contact or via a mechanical vector, such as a contaminated surface. Examples of direct zoonoses include rabies and brucellosis (Arshad et al., 2022).

Cyclo-zoonoses: These involve transmission processes that require multiple vertebrate hosts but no invertebrate hosts, for the lifecycle of the pathogen to complete. The disease agent does not change form but may require different hosts for different lifecycle stages. Diseases like hydatid disease and taeniasis fall into this category (Pal et al., 2022).

Meta-zoonoses: In these diseases, transmission involves invertebrate vectors that biologically transmit the pathogen. The pathogen may either multiply, develop, or both within the invertebrate host before it can infect a vertebrate host. This transmission process includes an extrinsic incubation period within the vector. Malaria and leishmaniasis are examples of meta-zoonoses (Ornellas-Garcia et al., 2023).

Sapro-zoonoses: These zoonoses involve a vertebrate host and a non-animal developmental site or reservoir, such as soil or organic matter, where the pathogen can thrive and multiply. Transmission to humans or other vertebrates occurs when there is contact with the contaminated non-animal reservoir. Histoplasmosis and hookworm infections are typical examples of sapro-zoonoses (Prabhu, 2023).

2. Vector-Borne Zoonotic Diseases

Anthrax

Herbivores are susceptible to anthrax, a zoonotic disease brought on by *Bacillus anthracis* that people can contract by coming into touch with diseased animals or their byproducts (such as wool or hides). The three main types of anthrax are gastrointestinal, inhalational, and cutaneous.

Cutaneous anthrax is the most commonly occurring form, when spores entering through skin abrasions. A painless papule is the first sign, and it develops into a necrotic ulcer with a black eschar. If left untreated, it might result in septicaemia.

Inhalational anthrax (wool sorter's disease) is caused by inhaling spores, often by workers handling contaminated animal products. Symptoms include flu-like illness, chest pain, and respiratory distress, rapidly leading to shock and death without prompt treatment.

Gastrointestinal anthrax results from ingesting contaminated meat, causing severe abdominal pain, vomiting, and bloody diarrhea (Alam et al., 2022).

One major problem is the persistence of *B. anthracis* spores in soil and animal remains. Since anthrax spores can persist in soil for over ten years, environmental reservoirs can cause the disease to reappear many years after the victim has died, resulting in intermittent outbreaks and possible zoonotic transmission. The geographic distribution of *B. anthracis* may be influenced by changing climate patterns, especially increased temperatures and extreme weather. These changes could enlarge the areas susceptible to anthrax outbreaks and transmit the illness to new places (Aborode et al., 2023).

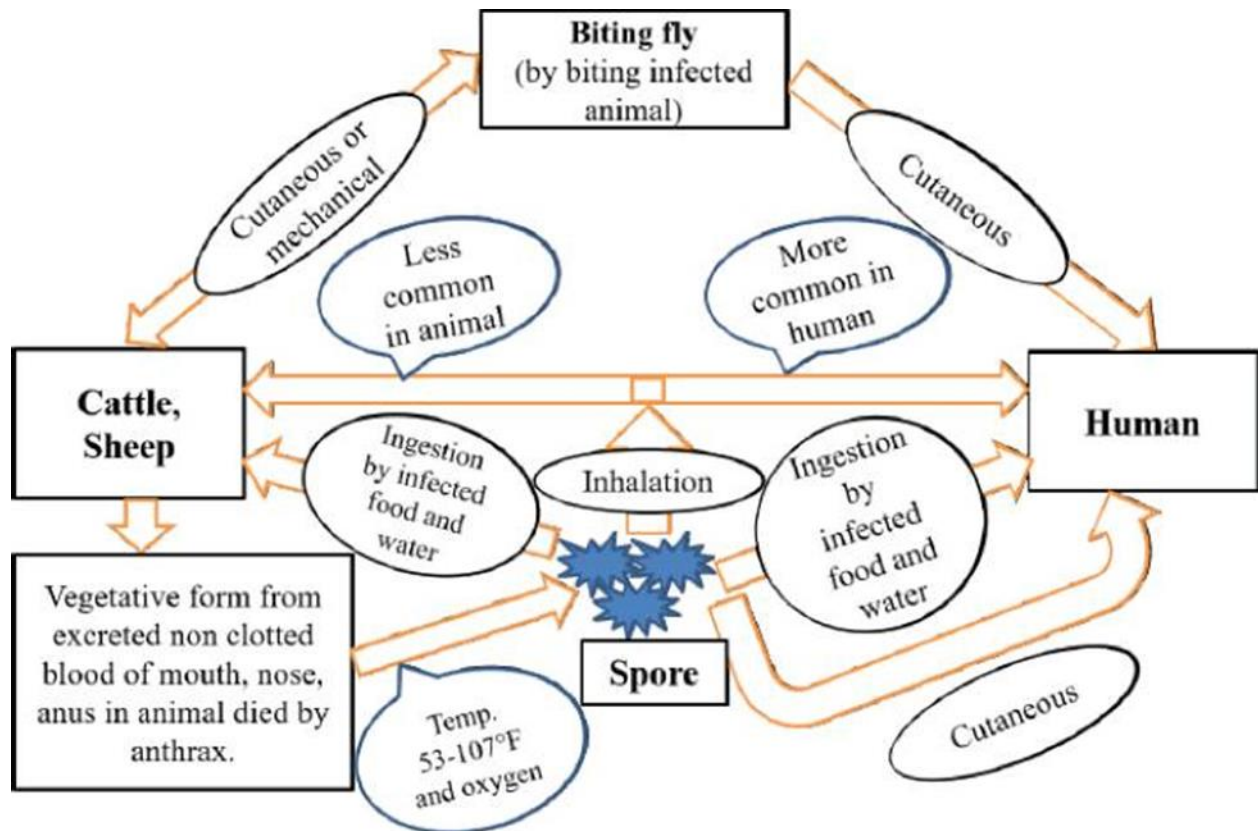


Fig. 1: Human, Animal and Environment Association

The standard treatment for anthrax patients is thought to be antibiotics (Stark, 2022). However, because of characteristics like the generation of toxins, the issue of antibiotic resistance, and the high incidence of meningitis, the treatment of anthrax is different from that of other bacterial illnesses (Dogonay et al., 2023). Penicillin G and amoxicillin are therefore the first-choice medications in naturally occurring anthrax cases, with doxycycline and ciprofloxacin serving as backups.

Vaccinating animals, providing protective gear to vulnerable people, and raising public knowledge of the dangers of handling tainted animal products are the main goals of prevention.

Implementing a complex strategy that includes hygienic measures, surveillance, avoiding contact with diseased animals or contaminated items, educational activities, increased awareness, and the use of antibiotics is necessary for the prevention and management of anthrax (Aborode et al., 2023).

Brucellosis

People can contract brucellosis, sometimes called undulant or Malta fever, by eating unpasteurised dairy products or by coming into close contact with animals that are affected (cattle, goats, sheep). The disease is endemic in regions with poor animal control and dairy processing practices. The most prevalent re-emerging zoonotic disease with a worldwide distribution is brucellosis. *B. suis*, *B. melitensis*, and *B. abortus* are the primary causes of the disease in humans. Due to challenges in vaccinating free-ranging goats and sheep, *B. melitensis* is the most common species causing human brucellosis worldwide (Olsen and Stoffregen, 2005).

Transmission happens by:

- Direct contact with animal fluids or tissues that are infected, or through cuts and abrasions on the skin.
- Consuming unpasteurised cheese or milk from animals that are affected.

Brucellosis typically presents with non-specific symptoms like fever, malaise, sweating, and joint pain. It is called undulant fever because of its characteristic relapsing fever. If untreated, chronic brucellosis may develop, leading to complications such as arthritis, hepatosplenomegaly, and even endocarditis (Jin et al., 2023).

The best course of antibiotic treatment for brucellosis remains controversial despite a great deal of research conducted in the last 15 years. For adults with acute brucellosis, the World Health Organization (WHO) recommends rifampicin 600–900 mg and doxycycline 200 mg daily for at least 6 weeks. However, some people continue to believe that the tried-and-true combination of oral tetracycline and intramuscular streptomycin results in fewer relapses (Bosilkovski et al., 2021). Long-term

care may be necessary; antibiotics are typically the cornerstone of treatment. Surgery may be necessary for certain localised diseases, such endocarditis (Siquier-Padilla et al., 2022).

Prevention

Mass vaccination is the primary method of preventing brucellosis in livestock, but it should be combined with additional tactics that limit the spread of the infection, make it possible to identify individual animals and herds, and increase community participation (Barrio et al., 2009). It focuses on the pasteurization of dairy products, vaccinating livestock, and protective measures for individuals working with animals. Public health campaigns are crucial in educating populations, especially in rural and farming areas, about the risks of unpasteurized dairy and direct animal contact.

Leptospirosis

People worldwide are afflicted by leptospirosis, a highly contagious zoonotic and waterborne illness (Pal, 2007; Guerra, 2013; Pal et al., 2021). *Leptospira* is thought to be primarily found in rodents. The most significant public health concern at the interface of animals, humans, and ecosystems is leptospirosis (Bulcha et al., 2021).

Transmission occurs through:

.Direct contact

The infection spread via skin contact with moist soil, water, and vegetation infected with the urine of infected animals as well as by the organism's penetration into the skin and mucous membranes by abrasion, cut, and damage (Bulcha et al., 2021).

Transmission may occur through consumption of infected food or drink. The symptoms of leptospirosis can vary greatly. Fever, headaches, muscle soreness (particularly in the calves), and red eyes are symptoms of the mild variety. The severe kind, called Weil's illness, includes respiratory distress, jaundice, haemorrhage, and damage to the liver and kidneys. It might result in renal failure and death if treatment is not received. **Management** includes giving antibiotics like penicillin or doxycycline. Hospitalization for supportive treatment in extreme situations (e.g., hydration, dialysis) may be required (Karpagam and Ganesh, 2020)

Avoiding contact with rats, cattle, pigs, horses, and other domestic animals that might spread leptospiral infections, as well as soil, agricultural lands, and water bodies in endemic areas, are common preventive methods. It is possible to advise farmers, agricultural labourers, freshwater athletes, and flood relief volunteers to use appropriate protective gear, such as boots and gloves, to avoid coming into contact with the infectious agent (Karpagam and Ganesh, 2020). Risky individuals, such as animal caretakers, healthcare workers, farmers, and field workers, should be warned and trained to avoid exposure, infection, or infection-transmission. It is necessary to create a leptospiral infection control program with qualified medical personnel (John, 2005).

Ebola Disease

The Ebola virus, which belongs to the Filoviridae family, is the cause of the severe and frequently fatal disease known as Ebola hemorrhagic fever. Humans contract it by coming into contact with infected wild animals such as fruit bats, chimps, gorillas, and porcupines. Direct contact with blood, bodily fluids, or infected surfaces can spread the disease from person to person. Family members and healthcare professionals are most vulnerable, particularly while handling a deceased Ebola patient's body during funeral procedures (Jacob et al., 2020).

The most common symptom is a high-grade fever of greater than 38 degrees Celsius, which is usually followed by other nebulous symptoms such headaches, sore throats, dry coughs, dysphagia, and overall malaise. The progressively advanced disease is accompanied by abdominal pain, myalgia, nausea, vomiting, and diarrhea (Wong and Wong, 2015). Ebola affects multiple organ systems and can lead to death due to organ failure. The fatality rate is extremely high, often reaching 70-90% without appropriate medical care.

Treatment focuses on **supportive care**, such as maintaining fluid balance, electrolytes, and oxygenation. Experimental have shown modest promise with antiviral medications and monoclonal antibodies. The **Ervebo vaccine** is used during outbreaks to protect at-risk populations, including healthcare workers (Kennedy et al., 2022).

Strict infection control procedures, appropriate PPE use, isolation of affected persons, and safe burial procedures are examples of prevention strategies. Public health efforts, including surveillance and community education, are essential to containing outbreaks in endemic areas like West and Central Africa.

Plague

Humans can contract the plague, a zoonotic illness brought on by the bacteria *Yersinia pestis*, by coming into close contact with infected animals like rodents or flea bites. Pneumonic, septicaemic, and bubonic plague are the three primary forms of the disease (Kwit et al. 2015).

- 1) **Bubonic plague.** The most prevalent type is bubonic plague. It happens when a person is bitten by an infected flea, which causes a bubo—a painful, enlarged lymph node. Fever, chills, headaches, and muscle aches are other symptoms. Sepsis may result from the infection spreading to the bloodstream if treatment is not received (Holmes et al., 2024).
- 2) **Septicemic plague** happens when the bacteria immediately enter the bloodstream, either as a result of an original infection or untreated bubonic plague. Fever, weakness, abdominal pain, and bleeding into the skin and other organs are some of the symptoms. The term "Black Death" comes from the tissue's potential to turn black (Glatter & Finkelman, 2021).
- 3) **Pneumonic plague** is the most serious and infectious kind. It damages the lungs and can spread from person to person by respiratory droplets. Breathing difficulties, coughing, chest pain, and a high fever are among the symptoms. Pneumonic plague is frequently lethal if antibiotics are not taken quickly (Cooley et al., 2023).

Treatment requires immediate use of antibiotics such as streptomycin, gentamicin, or tetracycline, which can reduce the high mortality rate. For more serious instances, supportive care—such as intravenous fluids and breathing support—is essential.

Controlling rodent populations, preventing fleas, and teaching humans to stay away from stray or wild animals in endemic areas are all examples of preventive approaches. In order to stop the spread of pneumonic plague during outbreaks, quarantine regulations and, in certain cases, vaccination are essential. Food handling/storage procedures, community sanitation standards, and environmental factors of the household and its surroundings are parameters that can increase human interactions with rodent reservoirs (Tadesse et al., 2024). An effective plague control strategy is mostly dependent on the provision of supplies and equipment, such as hand washing stations, sanitation guidelines, disinfectants (such as laundry soap, chlorine powder, and disinfectant sprays), and personal protective equipment (mondiale de la Santé and Organization, 2015).

Rabies

A fatal disease caused by the Lyssavirus. The bite or saliva of an infected animal is the main method that humans get rabies. The multi-host rabies virus can infect any warm-blooded animal; however, it is believed that dogs, raccoons, badgers, bats, and wild predators including foxes, jackals, wolves, and mongooses are the main natural carriers of the virus (Kumar et al. 2023). It impacts the central nervous system, causing inflammation in the brain and, if left untreated, death. **Urban rabies** and **wildlife rabies** are the two primary varieties.

Transmission happens by licks or bites on ripped skin or mucous membranes. Zinke's 1908 demonstration was the first recorded evidence that saliva serves as a significant means of rabies virus transmission (Brown et al., 2011). **Post-exposure prophylaxis (PEP)** is crucial after potential exposure and is categorized into three levels:

- **Category 1:** No PEP required (e.g., touching the animal or licks on intact skin).
 - **Category 2:** Rabies vaccine is administered (minor scratches or nibbling without bleeding).
 - **Category 3:** Immunoglobulin and the rabies vaccine are required in cases of bites, scratches, skin breaks, or mucous membrane contamination (Scholand et al. 2022).
- The clinical picture might vary greatly between species, within individuals of the same species, and even within a single individual's disease history fig.2. Fear, restlessness, anorexia or increased hunger, vomiting, diarrhoea, a mild fever, pupil dilatation, hyperreactivity to stimuli, and excessive salivation are some of the earliest clinical indications, which are frequently ambiguous (Balcha and Abdela, 2017). WHO recommends vaccination for high-risk populations. Pet immunisation, avoiding stray or wild animal contact, and timely PEP following exposure are further preventative measures.

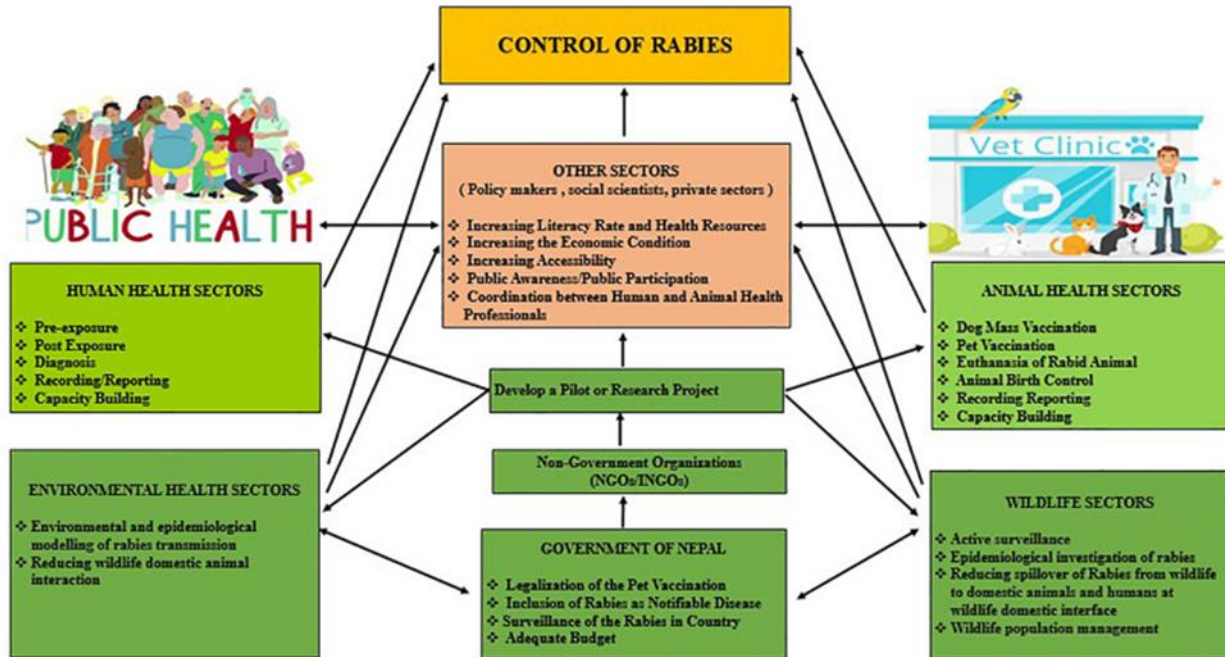


Fig. 2: Control of Rabies (Acharya et al. 2020)

The global strategy plan "Zero by 30" aims to eradicate dog-mediated rabies-related fatalities in humans by 2030. The World Health Organisation (WHO), the Food and Agriculture Organisation of the United Nations (FAO), the World Organisation for Animal Health (OIE), and the Global Alliance for Rabies Control are among the leading international health organisations spearheading this endeavour. Raising dog vaccination rates, raising awareness of rabies, and guaranteeing access to rabies post-exposure prophylaxis (PEP) globally are the main objectives of the strategic plan. The ultimate objective is to eradicate all rabies-related deaths in humans by 2030, with a focus on a coordinated and all-encompassing strategy involving several stakeholders from various health sectors (WHO, 2018).

Yellow Fever

Yellow Fever is a viral disease transmitted primarily by *Aedes* mosquitoes, particularly *Aedes aegypti*. It is common in South America and Africa's tropical and subtropical regions, where mosquitoes are the vectors. Fever and chills, exhaustion, headaches, myalgias, photophobia, lower back pain, appetite loss, nausea, and vomiting are all signs of yellow fever (Guarner and Hale, 2019). The severity can lead to significant fatality rates if not treated appropriately. Vaccination remains the most effective preventive measure against Yellow Fever, offering immunity and curtailing outbreaks effectively.

In regions where Yellow Fever is endemic, ongoing efforts to control mosquito populations and the implementation of mass vaccination campaigns are crucial to prevent large-scale outbreaks (Giancchetti et al., 2022).

The EYE strategy, a long-term, all-encompassing plan founded on lessons learnt, aims to stop yellow fever outbreaks by 2026 and has three strategic goals:

1. protect at-risk populations;
2. prevent international spread; and
3. contain outbreaks rapidly.

And five competencies of success:

- affordable vaccines and sustained vaccine market;
- strong political commitment at global, regional and country levels;
- high level governance with long-term partnerships;
- synergies with other health programmes and sectors; and
- research and development for better tools and practices

(mondiale de la Santé and Organization, 2017).

Japanese Encephalitis

One of the most dangerous vector-borne viral encephalitis diseases in the world, Japanese encephalitis (JE) is particularly prevalent in Asia, the Western Pacific region, and northern Australia (Erlanger et al., 2009). The disease is primarily transmitted

through the bites of infected *Culex* mosquitoes. Although JE can manifest in a variety of ways, severe instances might entail encephalitis, or inflammation of the brain, which can cause symptoms including convulsions, a high temperature, and even coma. Survivors frequently suffer from severe neurological or psychological aftereffects, and mortality rates are high. The mainstay of prevention is vaccination, which is combined with mosquito control methods to lower the risk of transmission (Wang et al., 2021). The comprehensive actions listed below ought to be implemented:

- 1) Including laboratory confirmation and virus isolation of JE to the surveillance system.
- 2) Including the JE vaccine in children's regular immunization schedules.
- 3) Mosquito vector control, improvement in the living environment, and health education are important (Wang and Liang, 2015).

Congo Fever (Crimean-Congo Hemorrhagic Fever)

A serious viral illness known as Crimean-Congo Hemorrhagic Fever (CCHF) is spread by ticks, especially those belonging to the *Hyalomma* genus. Additionally, it can be acquired by coming into touch with the blood, tissues, or bodily fluids of an infected person or animal. The most common disease spread by ticks is thought to be CCHF, which is caused by the Crimean-Congo hemorrhagic fever virus (CCHFV) (Nasirian, 2020).

The severity of CCHF varies, ranging from a mild, nonspecific febrile illness to shock, haemorrhage, vascular leak, and multi-organ failure. In addition to nausea, vomiting, diarrhoea, abdominal pain, and bleeding, it is characterised by an abrupt temperature, muscle aches, disorientation, headaches, neck, back, and eye pain. CCHF case-fatality rates might range from 30 to 50 percent. There is no vaccine available for CCHF; hence, prevention focuses on controlling ticks in livestock populations and personal protective measures for individuals at risk, such as farmers, veterinarians, and healthcare workers (Sharma et al., 2020).

Monkey pox

Monkeypox (MPX) is a viral zoonosis brought on by a double-stranded DNA virus (Di Gennaro et al., 2022). There are a number of ways that the monkeypox virus is thought to spread, but they are all linked to close contact with infected humans or animals (Kaler et al., 2022).

Acute fever exceeding 38.5 °C, headache, lymphadenopathy, myalgia, back discomfort, and asthenia are some of its clinical manifestations (Vaughan, Aarons et al. 2018). Currently, there are no accepted treatment protocols for MPX infection (Veronese et al., 2022).

Public health initiatives should prioritise early diagnosis, isolation, and case management in healthcare settings, with a focus on symptom recognition and the proper use of personal protective equipment (PPE), in order to stop the monkeypox virus from spreading. Healthcare professionals are required to follow stringent hygiene guidelines, establish isolation protocols, and guarantee environmental disinfection. In the community, contact tracing, cluster investigations, and targeted surveillance—particularly in high-risk populations—are crucial for detecting cases early, stopping transmission, and modifying control measures as necessary. In non-endemic areas, where even one case is considered an outbreak, prompt reporting to health authorities is essential (Alah et al., 2022).

3. Emerging Threats

Up to 75% of new or emerging infectious diseases (EIDs) and 60% of existing infectious diseases are thought to have zoonotic origins. Worldwide, zoonoses cause 2.7 million fatalities and 2.5 billion episodes of disease in people annually (Lee, 2022). The emergence and reemergence of zoonotic diseases are caused by a variety of interrelated and varied factors, which governments and international organisations must better understand. These factors include, but are not limited to, the invasion of natural habitats, particularly deforestation and rapid urbanization; the commercial trade in animals, both wild and farmed; and human activities that increase and spread disease risks, such as environmental pollution, improper use of vaccines and antimicrobials, and population movements around the world. Up until now, strategies have emphasised secondary prevention—preventing outbreaks from developing into an epidemic or pandemic—instead of primary prevention, which focusses on actions that stop outbreaks before the disease process starts. The latter comprises lowering risk exposures and regulating human actions that increase the risk of disease. The methods used now are still insufficient and incomplete (Street et al., 2024).

Public Health Solutions.

1) One Health Approach

The One Health idea acknowledges the interdependence of environmental, animal, and human health through an integrated approach Fig.3. It highlights the intimate relationship between human health and the health of animals and their shared environment. Among other health risks, this strategy is essential for combating vector-borne illnesses, food safety, antimicrobial resistance (AMR), and zoonotic diseases (diseases spread from animals to people). Since more than 60% of human infections are derived from animals, a comprehensive approach to health is essential (World Health Organization, 2022).

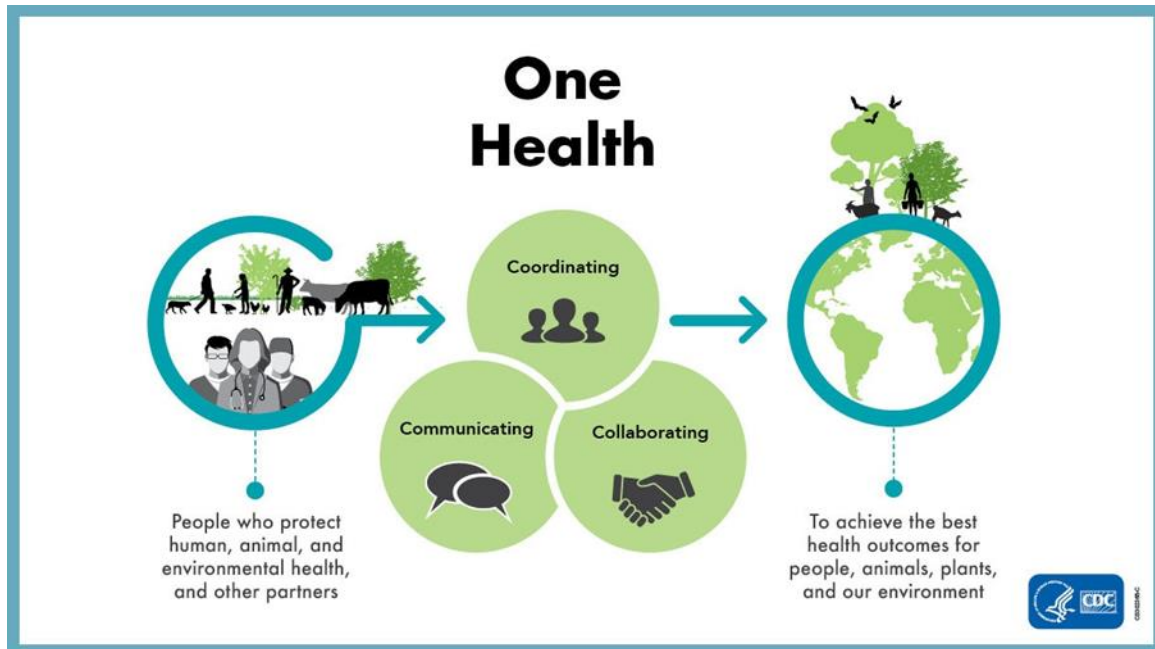


Fig. 3: The concept of One Health Approach

The foundation of the One Health approach is built upon communication, coordination, and collaboration among professionals from various sectors. These include doctors, veterinarians, environmental scientists, public health professionals, and policymakers. This multi-disciplinary collaboration aims to achieve optimal health outcomes for people, animals, and the environment.

In the One Health approach, veterinarians play a key role. They are responsible for the surveillance and control of animal diseases, healthy animals, promoting rational use of antibiotics to prevent antimicrobial resistance, and conducting vaccinations to prevent diseases that can spread to humans. Their role is particularly crucial in the food chain, where only healthy animals are sent to slaughterhouses, ensuring that the meat is safe for human consumption. The process includes pre-slaughter health checks, post-slaughter lab analysis, and continuous hygiene maintenance throughout the storage and market stages (Gupta et al., 2024).

The Hierarchy of Control and Its Application in Zoonotic Disease Prevention

A system called the Hierarchy of Control is used to reduce or completely eradicate exposure to environmental or occupational dangers. From the most effective (elimination) to the least effective (personal protective equipment, or PPE), it ranks control measures according to how well they reduce risk. In public health, this hierarchy is widely useful, especially in the avoidance of zoonotic diseases, which are transmitted between animal & humans (Ajslev et al., 2022).

1. Elimination

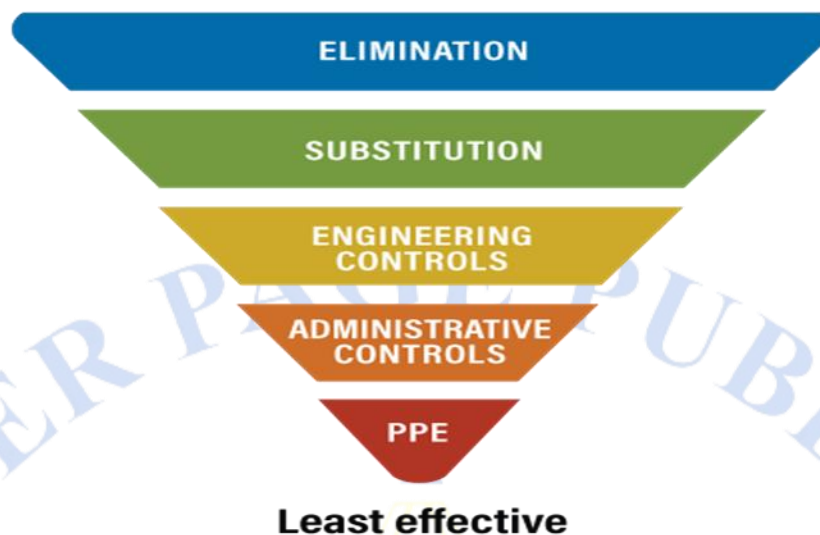
Elimination, or physically removing the threat, is the most successful type of control. In the context of zoonotic diseases, this could mean eradicating the disease from animal populations, such as vaccination programs to eliminate rabies in dogs or culling infected livestock during outbreaks of diseases like avian influenza (Carpenter et al., 2022).

2. Substitution

Substitution involves replacing the hazard with something less harmful. For zoonotic disease prevention, this means substituting live animals in markets with processed meat to reduce the risk of contact with diseases carried by animals, as seen in efforts to reduce the transmission of viruses like SARS and MERS Fig. 4 (Delahay et al., 2021).

Hierarchy of Controls

Most effective



Least effective

Fig. 4: Hierarchy of Control

3. Engineering Controls

Engineering controls involve isolating people from the hazard. For zoonotic diseases, this could include using barriers or physical structures to keep people away from potentially contaminated animals. For example, the use of enclosed animal housing or barriers in slaughterhouses can minimize the risk of infection (Mkangara, 2023).

4. Administrative Controls

Administrative controls refer to changes in work policies or procedures to reduce exposure to hazards. For zoonotic disease control, this can include public health guidelines such as vaccination, hygiene protocols, restricting access to areas with known outbreaks, or implementing animal quarantine measures. Training health workers and agricultural workers on handling animals safely also falls under this category (Titterington et al., 2022).

5. Personal Protective Equipment (PPE)

The least effective but often necessary control is PPE, which protects individuals from exposure. In zoonotic disease prevention, this includes wearing protective gloves, masks, and gowns when handling potentially infected animals or animal products. This is commonly used by veterinarians, health workers, and those working in high-risk environments like markets or slaughterhouses.

By applying the Hierarchy of Control systematically, the risk of zoonotic disease transmission can be minimized at every level, ensuring both animal and human populations are better protected (Levin et al., 2021).

5. Hazard Control / Intervention:

Recognizing and assessing potential zoonotic hazards, such as exposure to infected animals or contaminated products, is essential for workplace safety. Eliminating or substituting unsafe practices with safer alternatives, such as using processed products instead of handling live animals, can further reduce disease risk. By integrating these measures, zoonotic disease transmission in occupational settings can be minimized, ensuring the health and safety of workers and the broader community (Jain et al., 2021).

5) Challenges

The main challenges are:

A) Organizational

- (i) Policymakers' and decision-makers' lack of understanding of the disease's seriousness;
- (ii) Lack of knowledge regarding the prevalence, patterns, and dangers of zoonotic illnesses;
- (iii) Inadequate funding and qualified personnel for zoonotic disease management;
- (iv) The existence of competing health priorities that frequently take precedence;
- (v) The governments' lack of transparency in reporting the onset or prevalence of zoonotic diseases out of concern for the consequences;
- (vi) A lack of coordination or cooperation among the veterinary, agriculture, wildlife, and public health sectors;
- (vii) Insufficient coordination and partnerships to mobilise resources to support the zoonotic disease prevention and control program
- (viii) There is no communication between the clinical services, laboratory services, and surveillance divisions within the health sector.
- (ix) Removal of the health infrastructure's vulnerabilities, particularly in nations experiencing complicated catastrophes (Sänger et al., 2021).

B) Diagnosis and detection

- (i) The human and veterinary sectors are not integrated for the purpose of exchanging epidemiological and laboratory surveillance data between the human and health sectors;
- (ii) The disease surveillance system is weak, and the diagnostic capabilities to identify zoonotic infections are insufficient;
- (iii) Samples are difficult to transfer internationally for logistical and financial reasons.
- (iv) The majority of developing zoonotic epidemics occur in distant places, making field investigations challenging.
- (v) Inadequate monitoring, information sharing, and cooperation across borders (Gwenzi et al., 2022).

C) Control and interruption of transmission

- (i) Countries' inadequate ability to organise, mobilise, and carry out suitable control measures.
- (ii) There is a high risk of nosocomial transmission of certain recently discovered zoonoses in healthcare settings;
- (iii) Strict barrier nursing and other suitable infection control methods are not applied well in healthcare facilities.
- (iv) Insufficient knowledge on high-risk behaviours, such as social and cultural elements, that are linked to the community's risk of spreading newly emerging zoonoses;
- (v) Ineffective or inappropriate vector control measures.
- (vi) Some public health control measures lack or have inadequate evidence. (Lee, 2022).

Future perspectives

The ability of the national health authorities to react quickly and resolutely will be put to the test by these new diseases. Global health security will also be put to the test by how well regional and international communities can work together to combat these cross-border diseases. While international efforts should continue to close the existing knowledge gaps regarding the causes and spread of many zoonotic infections, many of which have novel origins, much more regional cooperation would be required to safeguard public health against all zoonotic infection types. The existing state of affairs in the area with respect to the regional and worldwide response to MERS-CoV should make it evident that a long-term public health program for the identification, prevention, and management of newly emerging zoonoses in the area is necessary. The "One Health" approach—a shared coordination mechanism, joint planning, joint implementation, community involvement, capacity building, and joint monitoring and evaluation framework between the animal health and human health sectors—should serve as the foundation for any strategic framework for the control of zoonotic infections. Additionally, the "one health" concept outlines five important areas where One Health is likely to have an impact. They are:

- (i) transferring medical and veterinary resources;
- (ii) managing zoonotic illnesses in animal reservoirs;
- (iii) early disease
- (iv) preventing pandemics and epidemics

(v) producing knowledge and enhancing health research and development

The strategy will also require the Member States to implement and coordinate measures that integrate technical, social, political, policy, and regulatory issues in order to enhance their ability to effectively mitigate the economic impact and public health burden that zoonotic diseases impose on their citizens and livestock. In order to prevent and control emerging and re-emerging zoonotic diseases in the WHO's Eastern Mediterranean Region, a workable plan must be put into action. The strategic directions outlined in this report are open for the Regional Committee to review and implement. As stated in the IHR (2005), effective control of emerging zoonoses will make the world safer from newly emerging and re-emerging pathogens and provide a chance to limit the health hazards of zoonotic illnesses that are of international significance.

Conclusion

With the discovery of MERS-CoV, the area is now a growing global health priority. Numerous newly discovered zoonotic infections have disproportionately affected the area. Current lessons include the fact that new zoonotic illnesses are unforeseen and unpredictable. The fact that any disease epidemic that occurs anywhere today could pose a threat to the world tomorrow is another lesson that has been learnt.

References

1. Aborode, A. T., Ojo-Akosile, T., Uwah, E. A., Ottoho, E., Ogunleye, S. C., Kamaldeen, A. B., ... & Ayoola, A. Y. (2023). The outbreak of anthrax in Nigeria: Re-enforcing one health. *New Microbes and New Infections*, 55.
2. Acharya, K. P., Acharya, N., Phuyal, S., Upadhyaya, M., & Lasee, S. (2020). One-health approach: A best possible way to control rabies. *One Health*, 10, 100161.
3. Ajslev, J. Z., Møller, J. L., Andersen, M. F., Pirzadeh, P., & Lingard, H. (2022). The hierarchy of controls as an approach to visualize the impact of occupational safety and health coordination. *International journal of environmental research and public health*, 19(5), 2731.
4. Alah, M. A., Abdeen, S., Tayar, E., & Bougmiza, I. (2022). The story behind the first few cases of monkeypox infection in non-endemic countries, 2022. *Journal of Infection and Public Health*, 15(9), 970-974.
5. Alam, M. E., Kamal, M. M., Rahman, M., Kabir, A., Islam, M. S., & Hassan, J. (2022). Review of anthrax: A disease of farm animals. *Journal of Advanced Veterinary and Animal Research*, 9(2), 323..
6. Arshad, R., Sargazi, S., Fatima, I., Mobashar, A., Rahdar, A., Ajalli, N., & Kyzas, G. Z. (2022). Nanotechnology for therapy of zoonotic diseases: A comprehensive overview. *ChemistrySelect*, 7(21), e202201271.
7. Balcha, C., & Abdela, N. (2017). Review of rabies preventions and control. *International Journal of Public Health Science*, 6(4), 343-350.
8. Barrio, M. B., Grilló, M. J., Muñoz, P. M., Jacques, I., González, D., De Miguel, M. J., ... & Zygmunt, M. S. (2009). Rough mutants defective in core and O-polysaccharide synthesis and export induce antibodies reacting in an indirect ELISA with smooth lipopolysaccharide and are less effective than Rev 1 vaccine against *Brucella melitensis* infection of sheep. *Vaccine*, 27(11), 1741-1749.
9. Bosilkovski, M., Keramat, F., & Arapović, J. (2021). The current therapeutical strategies in human brucellosis. *Infection*, 49(5), 823-832.
10. Brown, C. M., Conti, L., Ettestad, P., Leslie, M. J., Sorhage, F. E., & Sun, B. (2011). Compendium of animal rabies prevention and control, 2011. *Journal of the American Veterinary Medical Association*, 239(5), 609-617.
11. Carpenter, A., Waltenburg, M. A., Hall, A., Kile, J., Killerby, M., Knust, B., ... & Vaccine Preventable Zoonotic Disease Working Group. (2022). Vaccine preventable zoonotic diseases: challenges and opportunities for public health progress. *Vaccines*, 10(7), 993.
12. Cooley, K. M., Fleck-Derderian, S., McCormick, D. W., & Nelson, C. A. (2023). Plague Meningitis: A Systematic Review of Clinical Course, Antimicrobial Treatment, and Outcomes. *Health security*, 21(1), 22-33.
13. Delahay, R. J., de la Fuente, J., Smith, G. C., Sharun, K., Snary, E. L., Flores Giron, L., ... & Gortazar, C. (2021). Assessing the risks of SARS-CoV-2 in wildlife. *One health outlook*, 3, 1-14.
14. Di Gennaro, F., Veronese, N., Marotta, C., Shin, J. I., Koyanagi, A., Silenzi, A., ... & Smith, L. (2022). Human monkeypox: a comprehensive narrative review and analysis of the public health implications. *Microorganisms*, 10(8), 1633.
15. Doganay, M., Dinc, G., Kutmanova, A., & Baillie, L. (2023). Human anthrax: update of the diagnosis and treatment. *Diagnostics*, 13(6), 1056.

16. Erlanger, T. E., Weiss, S., Keiser, J., Utzinger, J., & Wiedenmayer, K. (2009). Past, present, and future of Japanese encephalitis. *Emerging infectious diseases*, 15(1), 1.
17. Giancchetti, E., Cianchi, V., Torelli, A., & Montomoli, E. (2022). Yellow fever: origin, epidemiology, preventive strategies and future prospects. *Vaccines*, 10(3), 372.
18. Glatter, K. A., & Finkelman, P. (2021). History of the plague: An ancient pandemic for the age of COVID-19. *The American journal of medicine*, 134(2), 176-181.
19. Guarner, J., & Hale, G. L. (2019, May). Four human diseases with significant public health impact caused by mosquito-borne flaviviruses: West Nile, Zika, dengue and yellow fever. In *Seminars in diagnostic pathology* (Vol. 36, No. 3, pp. 170-176). WB Saunders.
20. Guerra, M. A. (2013). Leptospirosis: public health perspectives. *Biologicals*, 41(5), 295-297.
21. Gupta, A. K., Fadzillillah, N. A., Sukri, S. J. M., Adediran, O. A., Rather, M. A., Naik, B., ... & Rustagi, S. (2024). Slaughterhouse blood: A state-of-the-art review on transforming by-products into valuable nutritional resources and the role of circular economy. *Food Bioscience*, 104644.
22. Gwenzi, W., Skirmuntt, E. C., Musvuugwa, T., Teta, C., Halabowski, D., & Rzymiski, P. (2022). Grappling with (re)-emerging infectious zoonoses: Risk assessment, mitigation framework, and future directions. *International Journal of Disaster Risk Reduction*, 82, 103350.
23. Holmes, C. L., Albin, O. R., Mobley, H. L., & Bachman, M. A. (2024). Bloodstream infections: mechanisms of pathogenesis and opportunities for intervention. *Nature Reviews Microbiology*, 1-15.
24. Jacob, S. T., Crozier, I., Fischer, W. A., Hewlett, A., Kraft, C. S., Vega, M. A. D. L., ... & Kuhn, J. H. (2020). Ebola virus disease. *Nature reviews Disease primers*, 6(1), 13.
25. Jain, A., Hassard, J., Leka, S., Di Tecco, C., & Iavicoli, S. (2021). The role of occupational health services in psychosocial risk management and the promotion of mental health and well-being at work. *International journal of environmental research and public health*, 18(7), 3632.
26. Jin, M., Fan, Z., Gao, R., Li, X., Gao, Z., & Wang, Z. (2023). Research progress on complications of Brucellosis. *Frontiers in cellular and infection microbiology*, 13, 1136674.
27. John, T. J. (2005). The prevention and control of human leptospirosis. *Journal of postgraduate medicine*, 51(3), 205-209.
28. Joint FAO/WHO Expert Committee on Brucellosis. (1986). *Joint FAO/WHO Expert Committee on Brucellosis: Sixth Report* (Vol. 6). World Health Organization.
29. Kaler, J., Hussain, A., Flores, G., Kheiri, S., & Desrosiers, D. (2022). Monkeypox: a comprehensive review of transmission, pathogenesis, and manifestation. *Cureus*, 14(7).
30. Karpagam, K. B., & Ganesh, B. (2020). Leptospirosis: a neglected tropical zoonotic infection of public health importance—an updated review. *European Journal of Clinical Microbiology & Infectious Diseases*, 39(5), 835-846.
31. Keshavamurthy, R., & Charles, L. E. (2023). Predicting emerging zoonotic disease under resource-limited settings: Case study of Kyasanur Forest Disease using event-based surveillance data and transfer learning.
32. Kilonzo, B. S., Mvena, Z. S. K., Machangu, R. S., & Mbise, T. J. (1997). Preliminary observations on factors responsible for long persistence and continued outbreaks of plague in Lushoto district, Tanzania. *Acta tropica*, 68(2), 215-227.
33. Kumar, A., Bhatt, S., Kumar, A., & Rana, T. (2023). Canine rabies: an epidemiological significance, pathogenesis, diagnosis, prevention, and public health issues. *Comparative Immunology, Microbiology and Infectious Diseases*, 97, 101992.
34. Kwit, N., Nelson, C., Kugeler, K., Petersen, J., Plante, L., Yaglom, H., ... & Mead, P. (2015). Human plague—United States, 2015. *MMWR Morb Mortal Wkly Rep*, 64(33), 918-9.
35. Lee, K. (2022). *The Global Governance of Emerging Zoonotic Diseases: Challenges and Proposed Reforms*. Council on Foreign Relations.
36. Levin, R., Vieira, C. L. Z., Rosenbaum, M. H., Bischoff, K., Mordarski, D. C., & Brown, M. J. (2021). The urban lead (Pb) burden in humans, animals and the natural environment. *Environmental research*, 193, 110377.
37. Mkangara, M. (2023). Prevention and control of human *Salmonella enterica* infections: An implication in food safety. *International Journal of Food Science*, 2023(1), 8899596.
38. mondiale de la Santé, O., & World Health Organization. (2015). Plague in Madagascar: overview of the 2014-2015 epidemic season. *Weekly Epidemiological Record= Relevé épidémiologique hebdomadaire*, 90(20), 250-252.
39. mondiale de la Santé, O., & World Health Organization. (2017). Eliminate Yellow fever Epidemics (EYE): a global strategy, 2017–2026—«Éliminer les épidémies de fièvre jaune»(EYE): une stratégie mondiale, 2017-2026. *Weekly Epidemiological Record= Relevé épidémiologique hebdomadaire*, 92(16), 193-204.

40. Nasirian, H. (2020). New aspects about Crimean-Congo hemorrhagic fever (CCHF) cases and associated fatality trends: A global systematic review and meta-analysis. *Comparative immunology, microbiology and infectious diseases*, 69, 101429.
41. Olsen, S. C., & Stoffregen, W. S. (2005). Essential role of vaccines in brucellosis control and eradication programs for livestock. *Expert review of vaccines*, 4(6), 915-928.
42. Ornellas-Garcia, U., Cuervo, P., & Ribeiro-Gomes, F. L. (2023). Malaria and leishmaniasis: Updates on co-infection. *Frontiers in Immunology*, 14, 1122411.
43. Pal, M. (2007). Zoonoses.
44. Pal, M., Alemu, H. H., Marami, L. M., Garedo, D. R., & Bodena, E. B. (2022). Cystic Echinococcosis: a comprehensive review on life cycle, epidemiology, pathogenesis, clinical Spectrum, diagnosis, public health and economic implications, treatment, and control. *Int. J. Clin. Exp. Med. Res*, 6(2), 131-141.
45. Pal, M., Bulcha, M. R., & Bune, W. M. (2021). Leptospirosis and one health perspective. *American Journal of Public Health Research*, 9(4), 180-183.
46. Prabhu, S. R. (2023). Infectious and Communicable Diseases: An Overview. *Textbook of General Pathology for Dental Students*, 63-72.
47. Rahman, M. T., Sobur, M. A., Islam, M. S., Ievy, S., Hossain, M. J., El Zowalaty, M. E., ... & Ashour, H. M. (2020). Zoonotic diseases: etiology, impact, and control. *Microorganisms*, 8(9), 1405.
48. Sängler, N., Heinzl, C., & Sandholz, S. (2021). Advancing resilience of critical health infrastructures to cascading impacts of water supply outages—insights from a systematic literature review. *Infrastructures*, 6(12), 177.
49. Scholand, S. J., Quiambao, B. P., & Rupprecht, C. E. (2022). Time to Revise the WHO Categories for Severe Rabies Virus Exposures—Category IV?. *Viruses*, 14(5), 1111.
50. Sharma, S. N., Singh, R., Balakrishnan, N., Kumawat, R., & Singh, S. K. (2020). Vectors of Crimean-Congo hemorrhagic fever (CCHF): prevention and its control. *Journal of Communicable Diseases (E-ISSN: 2581-351X & P-ISSN: 0019-5138)*, 52(3), 22-26.
51. Simon, J. K., Kennedy, S. B., Mahon, B. E., Dubey, S. A., Grant-Klein, R. J., Liu, K., ... & Grais, R. F. (2022). Immunogenicity of rVSVΔG-ZEBOV-GP Ebola vaccine (ERVEBO®) in African clinical trial participants by age, sex, and baseline GP-ELISA titer: A post hoc analysis of three Phase 2/3 trials. *Vaccine*, 40(46), 6599-6606.
52. Siquier-Padilla, J., Cuervo, G., Urrea, X., Quintana, E., Hernández-Meneses, M., Sandoval, E., ... & Miro, J. M. (2022). Optimal timing for cardiac surgery in infective endocarditis with neurological complications: a narrative review. *Journal of clinical medicine*, 11(18), 5275.
53. Stark, J. F. (2022). ‘A remedy for this dread disease’: Achille Sclavo, anthrax and serum therapy in early twentieth-century Britain. *The British Journal for the History of Science*, 55(2), 207-226.
54. Street, M. E., Shulhai, A. M., Petraroli, M., Patianna, V., Donini, V., Giudice, A., ... & Predieri, B. (2024). The impact of environmental factors and contaminants on thyroid function and disease from fetal to adult life: Current evidence and future directions. *Frontiers in Endocrinology*, 15, 1429884.
55. Tadesse, K. T., Demise, R., Mulat, F., & Zerfu, A. (2024). The Role of Post-Harvest Management in Ensuring Food Security in a Changing World: Review Article. *Journal of Clinical Research and Case Studies*, 2(3), 1-14.
56. Titterington, F. M., Knox, R., Buijs, S., Lowe, D. E., Morrison, S. J., Lively, F. O., & Shirali, M. (2022). Human–animal interactions with *Bos taurus* cattle and their impacts on on-farm safety: a systematic review. *Animals*, 12(6), 776.
57. Vaughan, A., Aarons, E., Astbury, J., Balasegaram, S., Beadsworth, M., Beck, C. R., ... & Wilburn, J. (2018). Two cases of monkeypox imported to the United Kingdom, September 2018. *Eurosurveillance*, 23(38), 1800509.
58. Wang, G. H., Gamez, S., Raban, R. R., Marshall, J. M., Alphey, L., Li, M., ... & Akbari, O. S. (2021). Combating mosquito-borne diseases using genetic control technologies. *Nature communications*, 12(1), 4388.
59. Wang, H., & Liang, G. (2015). Epidemiology of Japanese encephalitis: past, present, and future prospects. *Therapeutics and clinical risk management*, 435-448.
60. Wong, S. S. Y., & Wong, S. C. Y. (2015). Ebola virus disease in nonendemic countries. *Journal of the Formosan Medical Association*, 114(5), 384-398.
61. World Health Organization, UNEP United Nations Environment Programme, & World Organisation for Animal Health. (2022). One health joint plan of action (2022–2026): working together for the health of humans, animals, plants and the environment. World Health Organization.
62. World Health Organization. (2014). Field situation: How to conduct safe and dignified burial of a patient who has died from suspected or confirmed Ebola virus disease (No. WHO/EVD/Guidance/Burials/14.2). World Health Organization.

63. World Health Organization. (2018). Zero by 30: the global strategic plan to end human deaths from dog-mediated rabies by 2030.

