

Globalization and Livestock Biosecurity

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Abstract Globalization has resulted in enhanced trade in livestock and livestock products leading to increased risk of diseases to livestock and human beings. The emergence of highly contagious viral diseases of livestock and poultry such as foot-and-mouth disease, peste des petits ruminants, African swine fever (ASF), Newcastle disease, avian influenza and zoonotic diseases caused by viruses like Ebola, West Nile, Nipah, Hendra and swine influenza (H1N1) have necessitated the formulation of policies and regulatory frameworks for preventing ingress of exotic diseases and controlling dissemination of endemic diseases within the country. Biosecurity measures are important to maintain and improve animal health and reduce the risks. In this review, the risks of introduction of infections through livestock and livestock products, routes of transmission and general biosecurity measures to reduce these risks have been discussed.

Keywords Livestock biosecurity · Biosecurity · Farm biosecurity · Infectious diseases · Disease transmission

Introduction

Globalization has resulted in enhanced trade in livestock and livestock products, which accounts for nearly half of global agricultural economy. The enhanced trade has also resulted in increased risk of diseases to livestock and human beings [80]. Literature suggests that out of the 1,407 human pathogens, 816 (58 %) are of zoonotic nature and 73 % of emerging human pathogens are transmitted through animals [80]. The important reasons for high incidence of zoonotic and other infectious diseases of animals are breach in biosecurity in livestock management, closer contact between wildlife and humans and rearing of livestock and poultry in close association with people [9, 52]. The emergences of viruses like Ebola, West Nile, SARS-Corona, Nipah, Hendra, Avian influenza and

influenza virus H1N1 are examples of zoonotic diseases which have potential for threatening health, economies and food security around the world. Viral diseases like foot-and-mouth disease (FMD) occurred in countries where these had not been reported for many decades. If the dissemination of these pathogens occurs globally at fast pace, it will make the notion of ‘exotic diseases’ as meaningless in the countries free from particular infectious diseases. Highly contagious diseases of livestock and poultry such as FMD, peste des petits ruminants (PPR), African swine fever (ASF), Newcastle disease (ND) and avian influenza (HPAI) also disseminate globally. Disease incursions in the past have led to the establishment of many diseases in India. African horse sickness resulted in death of over 3,00,000 equids between 1959 and 1961 in Asia including India [48]. Since 1994, white spot syndrome caused severe production losses to the shrimp culture industry in China, Thailand, India and a number of other Asian countries [22, 30]. Since its first detection in 1996, H5N1 Avian influenza virus has spread to over 60 countries in Asia, Europe and Africa infecting wild birds or domestic poultry with sporadic zoonotic transmission to humans and raised pandemic concern [35, 57]. India and Bangladesh are experiencing

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outbreaks of H5N1 virus every year since their first detection in 2006 and 2007, respectively [25, 81]. These animal health emergencies have highlighted the vulnerability of the livestock sector to infectious diseases and the associated risks to human health, food security and global economies. Many countries also share a common concern about the natural occurrence or the risk from possible deliberate misuse of pathogenic agents. These infectious organisms can also be used intentionally as bioterrorism agents to devastate animal and human health. Animals could spread bio-warfare agents widely through animal-to-animal transmission and prove difficult to control, and thus, could multiply or propagate a bioterrorism outbreak [60]. Some important examples are the German use of *Burkholderia mallei* against Allied horses in Argentina and New Jersey during World War I, the Japanese use of *Yersinia pestis* in China during World War II, the Soviet use of tularaemia and glanders in Afghanistan and anthrax spore-laden letters of 2001 in the USA [38]. In 1997 in Berlin, pesticides dumped onto rendered-down animal products were sold as animal feed. Between 1975 and 1977 several threatening letters containing ticks allegedly infected with deadly diseases were used as part of an extortion campaign [1]. Most of the potential bioterrorist agents cause zoonotic diseases [20, 21]. Some biological warfare agents are capable of infecting a wide range of hosts [18]. Many countries have the scientific capacity to create new and novel organisms using simple tools of the modern biotechnology. Enhanced virulence or infectivity of organisms or creation of new pathogens using combinations of existing organisms is possible [26]. The same fundamentals of modern biology are also being used to create effective countermeasures against the threat of bioterrorism [15]. The use of animals as sentinels may help to detect exposure risks and provide an early warning for human diseases [60]. The impact of these diseases can be minimized through a strong public health system, and by developing a similar system developed for the livestock, wildlife and food safety sectors [50].

The World Organization for Animal Health (OIE) is responsible for developing standards and guidelines to prevent incursions of diseases during trade in animals and animal products. Since 1995, the standards developed by the OIE have been formally recognized by the agreement on the application of sanitary and phyto-sanitary measures (SPS Agreement) of the World Trade Organization (WTO). Existing methods of disease prevention and containment, regulations, guidelines and standards are being extended at both national and international levels to improve the ability of countries to prevent, manage and recover from natural, accidental or deliberate introduction of animal diseases.

Strategic and integrated approach encompassing the policy and regulatory frameworks that analyse and manage

risks in the sectors of food safety, animal and plant life and health, including associated environmental risk are referred as biosecurity [28]. Livestock biosecurity can be broadly defined as ‘any practice or system that prevents the spread of infectious agents from infected to susceptible animals, or prevents the introduction of infected animals into a herd, region or country in which the infection has not yet occurred’ [61]. It is all about knowing the risks to enterprise, understanding the ways in which animals can be exposed to disease and taking steps to minimize these risks. Biosecurity is crucial not only in preventing the disease ingress across the borders or spread of the disease within the borders but also in keeping the natural resources clean, fit for consumption and ensuring sustainability. The farmers have been using antimicrobials and vaccines to protect livestock from diseases. Due to frequent vaccination failures, evolution of antimicrobial resistance and emerging resistant strains of pathogens, these approaches are no longer effective. In many countries, current policies restrict the use of antimicrobials as feed additives [14]. Modern farming demands a more holistic approach that incorporates biosecurity for protection from animal diseases. Increase in intensively managed farms for industrial production of livestock and livestock products has enhanced the risk potential of introduction and spread of diseases warranting stricter biosecurity protocols for these premises. Freedom from serious animal diseases and pests is essential to meet the standards of livestock and livestock products to have access to national and international markets. Biosecurity is important to improve or maintain animal health and reduces the risk of the introduction and spread of endemic and foreign diseases. Animal diseases can spread from farm to farm and result in animal sickness, death and economic losses. In addition to adverse effects on the economy, there can be negative effects on the environment and human health. The best defense is to implement effective biosecurity practices.

The review focuses on the risks of introduction of infections with increasing trade in livestock and livestock products, routes of transmission and general biosecurity measures to reduce these risks.

Modes of Disease Transmission

Before devising biosecurity plans for the control of animal diseases, it is pertinent to understand the etiology and their modes of transmission. The diseases may result from a number of factors including infectious organisms, toxins, trauma or damage to a tissue or organ, or metabolic, nutritional and degenerative conditions. However, a primary cause is infection from pathogens, namely viruses, bacteria, fungi and parasites. Prenatal and venereal routes

also are direct means of disease transmission. Indirect transmission occurs through contact with infected or contaminated inanimate objects like needles, vehicles, farm equipment and environmental fomites from contaminated soil, food, water and animate vectors. Visitors and farm workers are animate vehicles when they carry pathogens on their clothing, shoes and hands between animals and farms. Arthropods (ticks, mites, flies, mosquitoes and fleas), birds, wildlife and other animals that transmit a pathogen from an infected animal to a susceptible animal act as animate vectors. Pathogens can invade susceptible animal hosts by five primary routes, namely respiratory route, skin contact, ingestion of contaminated food or water, reproductive transmission through semen or sexual contact with infected animals and through blood by injections with contaminated needles or bites of insect vectors.

Livestock Trade and Disease Outbreaks

Diseases can be transmitted directly from an infected animal to susceptible animal when it comes in close contact and is exposed to its secretions or excretions. Several occasions have been documented where trade in livestock and livestock products has been implicated in the spread of diseases. For instance, small ruminants were deemed responsible for epizootics of FMD in cattle in Tunisia in 1989, Greece in 1994, Southeast Asia in 1999 and Turkey in 2001. Goats were also implicated in an outbreak of FMD in Kuwait with type Asia 1 when infected goats with this strain were imported from Bangladesh [40]. Trade in goats and sheep has been implicated in the spread of an epizootic of PPR in Bangladesh in 2001. The importation of millions of sheep and goats into Mecca in the weeks prior to Eid ul-Adha and their subsequent halal slaughter has been associated with the occurrence of Rift Valley fever (RVF) in humans. The movement of animals from the Horn of Africa to Saudi Arabia is credited with the introduction of RVF into the Arabian Peninsula [31].

The trade in small ruminants and their products also merits consideration because sheep and goats may transmit zoonotic diseases such as RVF, Crimean Congo haemorrhagic fever (CCHF), brucellosis and listeriosis. They may also transmit highly infectious livestock diseases, such as PPR, to naive populations of small ruminants in other countries. In addition, sheep and goats can serve as an important source of FMD virus infection for cattle [66]. The movement of large numbers of sheep and goats from rural areas to the cities in the weeks preceding Eid, followed by the mass slaughter and butchering of these animals, has been associated with cases of CCHF in humans in Pakistan [62]. The use of unpasteurised sheep or goat milk

in traditional cheese recipes can be associated with the transmission of zoonotic diseases like brucellosis and listeriosis. The main pathogen associated with trade in wool and goat fibres is *Bacillus anthracis*. The pulmonary form of anthrax, known as ‘wool sorters disease’, occurs mainly in workers handling bales of raw fibre. Raw, unprocessed skins are a potential source of FMD and occasional cases of inhalation anthrax in people playing or having contact with the drums made of goat skin. Scrapie was introduced into Australia, New Zealand, South Africa, Kenya, Brazil and Colombia as a result of sheep importations from the UK occurring between the 1930s and 1970s. In the 1970s, pure-bred dairy goats of the European breeds originating from the United States and Europe resulted in the introduction of caprine arthritis encephalitis virus infection into some importing countries. Paratuberculosis due to *Mycobacterium paratuberculosis*, another chronic disease of small ruminants, also poses risks in the trade of breeding animals.

Similarly, movements of pigs and associated trade in pig products also play an important role in the spread of diseases. Environment provided by high-density pig production may lead to increased replicative and infectious efficiency on the part of viruses, possibly with higher pathogenicity [24]. The potential animal health risks from pig meat were reviewed by Farez and Morley [29]. They concluded that FMD, ASF, classical swine fever and swine vesicular disease posed significant risks in uncooked pork products [58].

The infection with H5N1 HPAI virus has been detected in healthy wild birds, poultry meat, internal contents of eggs and from swabs or washes of the egg shell of chickens, ducks and quails. Untreated blood, viscera and feathers have also been shown to harbour virus under natural or experimental conditions. Wild birds can indeed carry the virus to areas unaffected previously. The rates of detection of HPAI viruses in poultry meat are higher during the early stages of infection, indicating an elevated risk linked to the trade of meat collected in the pre-clinical or early clinical phases of the disease [6]. HPAIV, NDV and infectious bursal disease virus-1 are the most significant pathogens that might reasonably be expected to be spread through international trade of poultry meat [16]. The international trade in poultry hatching eggs, like that in poultry meat, may present an opportunity for the global spread of disease caused by HPAIV, NDV, *Mycobacterium gallisepticum* and *Mycobacterium synoviae* [17]. Globalization has resulted in creation of new pathways to supply wildlife and wildlife products, in the form of exotic companion animals, trophies, crafts, bushmeat (food) and both modern and traditional medicines. The trade in wildlife and wildlife products represents a significant pathway of risk for spread of pathogens to humans, domestic animals and other wildlife [71].

Biosecurity in Indian Context

Biosecurity measures at national level incorporate the components of ‘external biosecurity’ preventing ingress of trans-boundary animal diseases (TADs) and ‘internal biosecurity’ within the country encompassing zonal, compartmental and farm level biosecurity.

Biosecurity at International Borders

Country is at risk for a number of TADs like Plague, Lyme disease, Contagious equine metritis, *Salmonella abortusequi*, HPAI, FMDV (SAT 1-3), Lyssa-virus, Hendra, Nipah, West Nile fever, highly pathogenic ND virus, Rabbit haemorrhagic disease, Bovine spongiform encephalopathy, African horse sickness, Equine encephalomyelitis (EEE, VEE, WEE), Equine infectious anaemia, Vesicular stomatitis, RVF, Malignant catarrhal fever and other transmissible spongiform encephalopathies of sheep, goat, deer etc. Biosecurity measures are required for preventing and containing the ingress of these diseases through international trade. The OIE has facilitated safe trade in animals and animal products by developing effective standards to prevent the spread of animal diseases across the globe. Prevention of transmission of pathogens across intra and inter country borders entails devising biosecurity measures at par with international standards. Adequate infrastructures in terms of check posts and quarantine facilities at seaports, airports and porous land border are must to check the ingress of pathogens. Failures in compliance with quarantine requirements can also be contributing factor in spreading infections as in case of 2007 outbreak of equine influenza in Australia [76].

Diagnostic facilities equipped with instruments, pen-side diagnostic tests/kits and trained human resources should be in place for ensuring pathogen-free status of imported livestock and livestock products.

The Livestock Importation Act, amended in 2001 by the Livestock, (Importation) Amendment Ordinance, provides for the regulation of the import of livestock which is liable to be affected by infections or contagious disorders. The import of livestock and livestock products in India is permissible through the international airports at Delhi, Mumbai, Kolkata, Chennai, Hyderabad and Bangaluru. Besides monitoring the imports at the airports, the animal quarantine stations at Mumbai, Chennai and Kolkata also take care of the imports taking place through the sea-ports of these cities. The livestock and livestock products on arrival are subjected to quarantine inspection, laboratory examination and disinfection before being permitted to enter into the country. India is signatory to WTO, and for fulfilment of its international obligations, can impose only

those sanitary measures which are scientifically justifiable and not unduly restrictive to international trade. However, this would need to be carried out in a manner which would mitigate the threat of ingress of diseases or alien pathogen(s) through import without being unnecessarily trade-restrictive. India has contiguous and porous borders with countries like Nepal, Bhutan, Pakistan and Bangladesh and also free trade with Nepal and Bhutan. These countries are vulnerable for TADs. As such, there is a need for regional biosecurity plan to ensure a biosecure region. These countries also need to implement biosecurity measures otherwise other neighbouring countries will always be at risk. It would never be possible to have biosecure India if the bordering countries do not have effective biosecurity in place.

Biosecurity Measures at National Level

In 2006–07, H5N1 HPAI was detected in Maharashtra, Gujarat, Madhya Pradesh, Manipur and the outbreaks were successfully contained by the implementation of the action plan of Department of Animal Husbandry, Dairying and Fisheries, MOA, Government of India. Biosecurity measures were central to this action plan [25]. Options for trade from disease-free zones, disease-free compartments and trading in safe commodities are now available to have positive mechanism for facilitating international trade [10]. In India, FMD-Control Program is already in operation with the aim to create FMD free zones. Similar zones can be created for other diseases like HS, Bluetongue, sheep pox, goat pox, PPR and a few other important diseases. In 2005, the OIE’s *Terrestrial Animal Health Code (Terrestrial Code)* introduced the concept of compartmentalization on the basis that domestic livestock could be effectively isolated from other mammals and birds. Animals or products derived from livestock within these compartments could be safe to trade. A comprehensive biosecurity plan for each compartment is developed with detailed description of the standard operating procedures, contingency plans, surveillance and reporting systems, and training programmes [63]. Creation of zones/compartments will definitely ensure boost in international trade of livestock and poultry products. In India, legislation regarding the movement of animals across these zones and compartments is required. Regulations for animal movement through inter-state borders in India are in place but are rarely implemented in letter and spirit, thus leading to un-inhibited and un-checked animal movements across inter-state borders. This requires convincing the state authorities and the government about usefulness and economic benefits of implementation of biosecurity. Modern detection systems can be used for identification and tracking of animals and

animal products [44] to provide information regarding origin of animal and environmental practices used in production, food safety and other records related to animal welfare issues to stakeholders and consumers.

Farm Biosecurity

Farm biosecurity combines ‘bio exclusion’, *i.e.* measures for preventing a pathogen from being introduced to a herd/flock and ‘bio containment’, which addresses events after introduction, *i.e.* the ability for a pathogen to spread among groups of animals at a farm or, more generally, in terms of releases from the farm [19]. Disease transmission between farms depends on the combination of individual bio-exclusion practices and bio-containment measures. Integration of biosecurity into every operation at the farm is essential.

Risk Assessment and Biosecurity Plan

The ability to withstand an outbreak is influenced by biosecurity plan and its effective implementation. Farm biosecurity plan involves a rational risk assessment and careful planning to manage the targeted risks. Risk assessment is the evaluation of the likelihood and the biological and economic consequences of entry, establishment or spread of a hazard within the territory [42]. Universal biosecurity measures cannot be recommended owing to variable management practices at different farms. On-farm risk assessment is the best starting point for educating farmers about farm-specific risks for disease introduction [67]. Diseases with the greatest risk should be prioritized and practices should be aimed to check the transmission of these diseases. A biosecurity plan should address important issues including location and layout of the farm, animal health practices and general management on the farm. An effective biosecurity plan should be flexible and open to new knowledge and technology. A wide range of biosecurity practices has been recommended for different livestock species and production systems either for general disease prevention, or specific infection risks. These studies have recommended biosecurity practices for cattle [3, 12, 27, 45, 49, 68, 69, 75], sheep [37, 65], pig [59, 64], poultry [73], alpaca [2] and fish [41] production systems. Strict implementation of biosecurity at farm level has played a crucial role in preventing the spread of diseases. The authors experienced this paradigm in two instances, when equine influenza and *Rhodococcus equi* infections were successfully controlled by application of simple biosecurity measures (unpublished report). General biosecurity practices including biosecurity interventions that can be applicable across species and farms are given below.

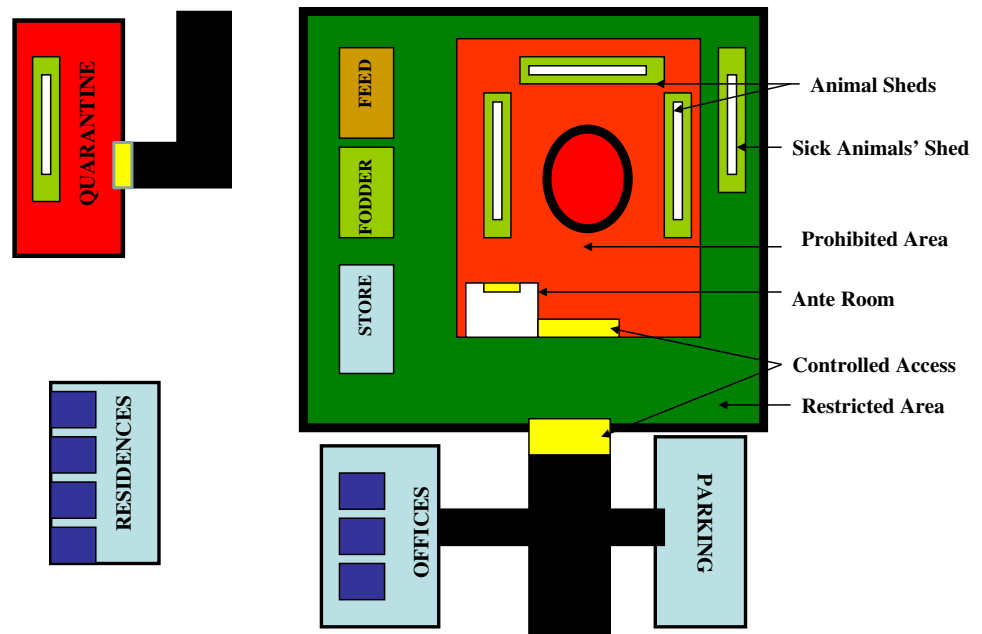
Location and Layout of the Farm

The natural environment surrounding the farm is important for understanding the disease risks [56]. Risk of diseases increases manifold if the farm is located in the vicinity of other farms, abattoirs, livestock markets, waste disposals, hatcheries and carcass centre. The location closer to animal transport routes and waterways also adds to the risk. Orientation of barns, buildings, ventilation inlets and outlets, unloading and loading areas, treatment and isolation or quarantine locations should be designated in such a manner that minimizes the risk of disease introduction and spread [13]. Segregated rearing areas for young, sick and new animals with visibly demarcated boundaries reduce the risk of disease transmission. Natural features, including vegetation, waterways and topography, can benefit a biosecurity plan by providing natural barriers and drainage.

Purchase and Introduction of New Animals

Purchase of animals, where incoming stock remains in direct contact with the recipient herd for an extended period of time, presents the highest risk for introducing infectious hazards [47]. Maintaining a closed herd is the most important biosecurity measure [74]. However, even specific-pathogen-free and closed herds experience disease breakdowns [72], reflecting the important role of other transmission routes. Minimizing the number of animals purchased and the herds from which the animals are purchased reduces the risk of introduction of infectious agents [4]. Purchases from markets or dealers present a very high-biosecurity risk. The animal health practices include appropriate quarantine and testing of animals upon introduction or reintroduction in farm premises. Purchase or reintroduction of animals after visit to fairs, exhibitions etc. has the potential to introduce disease-causing agents. Farming practices, such as hiring a bull and returning it after the breeding season, significantly increase the risk of entry of venereally transmitted infections [5, 7]. The animals should be procured from sources following biosecurity practices. Avoiding introduction of biological material of uncertain health status is the best method of avoiding risk [32]. The health and vaccination records should also be obtained for these animals. Isolation/quarantine of such animals for at least 2–8 weeks in a separate quarantine facility is essential for preventing introduction of pathogens. The animals during this period should be observed frequently for illness or abnormal behaviour and should be screened for important diseases before mixing with other animals. Laboratory testing prior to animal introduction is commonly recommended for many infectious diseases and can greatly enhance the sensitivity of detecting an infectious animal, and therefore reduces risk [45, 51]. Incoming

Fig. 1 An example of layout plan of a biosecure animal house showing different zones for movement of animals and visitors



stock can be treated prophylactically to reduce the risk of introduction of infectious agents [36]. Treatment with parenteral antibiotics, anthelmintic and flukicide, antibiotic foot-bathing and vaccination has been recommended [41]. Vaccination should be completed at least 2 weeks before release from quarantine [11]. Prophylactic vaccination, against the disease(s) endemic in the area, helps to boost protective immunity and protection in the animal(s).

Management Practices at the Farm

Developing, implementing and maintaining good farm management practices allow biosecurity plan to operate effectively and provide animals with an environment that is conducive to good health and maximum production. Good animal husbandry practices and good agricultural practices further help in making the biosecurity plan very effective.

Movement within the Farm Premises

Movement of owners, employees, visitors, veterinarians and services is daily occurrences for a farm operation, which increases the risk of introduction and spread of diseases. Measures can be developed and implemented to reduce these risks. The access to farm premises should be restricted by establishing distinct zones with varying levels of protection. These zones should be defined with boundaries and appropriate signs. Movements of people into a designated zone, out of a designated zone and between the designated zones can be controlled through the use of controlled access points [13]. Separate foot wears and clothing for entrance into the different premises of farm are

required. Footbaths and hand wash facilities in transition area at the entrance and exit, entry and exit through controlled entry/exit point, clean-to-dirty, healthy-to-sick and young-to-old work patterns are some of the biosecurity measures to be followed at the farms. Vehicles can be a source for the introduction, spread and release of disease-causing agents. Thus, it is important to restrict the movement of vehicles, wash and disinfect tyres of vehicles before leaving or entering farm premises. Wheel dips of appropriate length suitable for all sizes of tyres should be made at the entry and exit of the farm premises. Parking areas, delivery and drop-off points should be designated using appropriate signs to direct their movement. An example of layout plan showing different zones for a biosecure animal farm is given in Fig. 1. The design can be modified as per the specific requirements and the animal species reared on the farm.

Animal Feed, Water and Bedding

Ingestion of contaminated feed, water or contact with contaminated bedding can introduce and spread diseases. Feed stored in humid and tropical climates often gets infested with fungi and their toxins. It is important to ensure that feed is not contaminated. Quality of feed and bedding materials should be checked periodically and before use. Regular testing of water, soil, feed and fodder is very important while implementing biosecurity plan at farm level. Water sources get contaminated with feces or urine and have the potential to expose animals to disease-causing pathogens and should be cleaned regularly. Slurry and dirty water can be a biohazard with *Escherichia coli*

O157, *Salmonella* and *Campylobacter* surviving for up to 3 months [54].

Disposal of Manure

Manure is an animal product that not only contains large quantities of pathogens but also attracts insects and pests. When it is disposed in fields without any pretreatment, it poses an opportunity for human contact and risk of transmission of pathogen, posing biosecurity threat [53]. Biosecurity measures include manure management plan to address collection, storage, handling and disposal. It should be outside of the production area. Biological composting and anaerobic storage are required before spreading manure in the fields. It should also be ensured that neighbouring producers do not spread manure adjacent to production areas or water sources. Contaminated beddings, animal products, manure, feed and fodder residues also need to be disposed away from the farm area.

Disposal of Carcasses

Carcasses act as a reservoir of pathogens, attract pests and source of transfer for pathogens. Various carcass disposal methods, including burial, landfill, incineration, rendering, composting and alkaline hydrolysis, have been reviewed by Nutsch and Kastner [55]. Different factors like animal species affected, the type of disease, number of carcasses involved, the availability and capacity of disposal options and other considerations unique to individual locations determine the most appropriate method of disposal. Biosecurity agencies in Australia, New Zealand, USA and Canada have recognized the potential benefits of composting for both routine and emergency management of mortalities, and have identified it as a preferred method of carcass disposal [23]. Composting is particularly suitable for broiler-farm mortalities and litter [77].

Pests, Feral Animals and Wildlife

The farming of animals provides favourable environment for pests which can be direct vectors for disease-causing agents. They can spread disease through movement and create a food chain that attracts more and possibly higher risk pests. Stored livestock feed and harvested crops may attract rodents and other predators [70]. The wildlife activity may also pose the risk of spreading pathogens such as *Brucella*, *Trichinella* [33], *Mycobacterium avium paratuberculosis* [34] and *Leptospira* [79]. *Neospora caninum* is a coccidian parasite of domestic dogs [39, 78], and *Cryptosporidium parvum* infection is prevalent in a range of mammalian and avian wildlife, resulting in environmental contamination which can be transmitted to farmed

livestock [43]. *Clostridium botulinum* intoxication of cattle has been associated with poultry litter contamination of pasture [46]. Wild deer are potential source of broad range of bacteria, viruses and parasites for livestock [8].

This problem can be dealt by devising and implementing an integrated pest management program. The measures vary depending on the geographic area and the wildlife species involved, which involve cutting grass and vegetation around the farm premises, monitoring rubbish dumps and debris piles, managing feed spills and food sources to discourage pests and wildlife. Secured entry points to animal housing, pens and barns; prevent pest, pets and wildlife access.

Cleaning and Disinfection

Cleaning and disinfection are key pillars of a strong biosecurity plan [13]. Cleaning and disinfection reduce pathogen load on people, equipment and vehicles, which mitigate the risk of pathogen movement between and within production areas [56]. Cleaning and disinfection of production areas, quarantine sheds and equipments after each production cycle are helpful. Shared and reusable equipments between animals need to be cleaned and disinfected before and after use. Animal feeders, water channels and feeding areas should be cleaned regularly. Cleaning and disinfection of feed delivery equipments, equipments that are in contact with mortalities, manure or feed are some of the measures relating to biosecurity considerations on a farm. Disinfection of liquid effluents from contaminated areas should also be performed before disposal. Certified and internationally accepted disinfectants must be used at farm premises.

Identification and Treatment of Sick Animals

The ability to react quickly and effectively to a disease situation is vital to minimizing the impact on an operation and helps in preventing disease spread. Detection of a disease concern at an early stage can help in minimizing its impact and facilitating its containment. Sick animals can easily transmit disease through direct or indirect contact. These animals should be isolated from healthy animals and investigated. Reservoirs for certain diseases and positive reactors should be culled from the herd as these animals can shed the pathogen and infect other animals. Routine testing and screening of animals for diseases should be performed to ascertain the health status of the herd. Implementing proactive measures will help in reducing the risk of disease becoming established on a farm. The appropriate use of medication can improve the efficacy of treatment. Vaccination and deworming schedules should be

developed and followed rigorously. Proper records of treatments and vaccinations should be maintained.

Conclusions

Intensification of livestock agriculture to meet the growing demands for proteins of animal origin, globalization, degradation of natural resources and global climatic changes has increased the risk of spread of animal diseases. Minimizing the huge economic losses and spread of zoonoses due to animal diseases as well as production of safe food underlines the need for appropriate disease control and prevention measures in animal husbandry. Huge resources are required to eradicate animal diseases especially in developing countries. Instead, controlling the spread of diseases is economically viable option and can ensure high rates of return. This can be easily facilitated to a great extent by effective implementation of biosecurity at different levels. Therefore, scope of biosecurity is constantly expanding and there is need to enhance biosecurity by developing policies at compartmental, zonal, regional and national level after due pest risk analysis. It is the mainstay in developing an economically feasible and practically viable biosecurity plan in a particular context. The review has highlighted the relative importance of biosecurity risks and the key protocols which can be useful for preventing the spread of animal diseases and production of food safe for human consumption.

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