Global Veterinaria 21 (1): 24-34, 2019
ISSN 1992-6197

DOI: 10.5829/idosi.gv.2019.24.34

Anthropogenic Influences in the Emergence of Viral Zoonoses: Implication for Food Security

Endrias Zewdu Gebremedhin

Ambo University, College of Agriculture and Veterinary Sciences,
Department of Veterinary Science, P. O. Box 19, Ambo, Ethiopia

Abstract: Emerging zoonoses are global public health problems. About three-quarters of these emerging infectious diseases are zoonotic, mainly of viral origin often crossing from their natural animal hosts to humans over the last few decades. Emerging viral zoonoses affect not only the health of humans, domestic and wild animals but also the economies of nations more so in developing countries than developed nations. To discern the anthropogenic influences in the emergence of viral zoonoses, this review discussed on those well documented factors such as change in land use, population expansion, urbanization, human encroachment, deforestation, modern agricultural practices, bush meat consumption, modern transport, live animal trade, international travel / ecotourism and climate change. The review was concluded with a section directed at discussing the prevention, rapid detection and containment of emerging viral zoonoses through capital investment, capacity development, surveillance, multidisciplinary collaboration under "*one health*" concept, use of modern information communication systems, modification of veterinary and medical curricula and public education.

Key words: Emerging Viral Zoonoses · Anthropogenic Influences · One Health · Surveillance.

INTRODUCTION

The concept of emerging infectious diseases appeared in the late 1980s, when major outbreaks occurred around the globe and surprised many scientists who considered infectious diseases to be maladies of the past or limited to the under-developed world [1].

There are about 1415 pathogens affecting mankind [2]. Emerging infectious diseases (EIDs) are defined as diseases that have recently increased in incidence or geographic range, recently moved into new host populations, recently been discovered or are caused by newly-evolved pathogens [3]. The majority of pathogen species (over 60%) causing diseases in humans are zoonotic [4]. As indicated by Chomel [1], majority of emerging infectious diseases seem to be caused by pathogens already present in the environment, brought out of obscurity or given a selective advantage by changing conditions and afforded an opportunity to infect new host populations. Zoonoses have been defined as "diseases and infections that are naturally transmitted between vertebrate hosts and man" [5, 6]. Zoonotic infections have long been considered an important category of emerging diseases, with animal reservoirs providing a source of new infections for humans throughout evolutionary history [7]. An estimated 75% of emerging infectious diseases are zoonotic, mainly of viral origin and likely to be vector borne [2]. In some emerging viral zoonoses, notably Nipah virus, West Nile virus (WNV) and Hanta virus infections, direct or vector mediated animal-to-human transmission is the usual source of human infection, animal populations are the principal reservoir of the pathogen and horizontal infection in humans is rare. While in other emerging viral zoonoses such as human immunodeficiency virus (HIV)/acquired immune deficiency syndrome (AIDS), certain influenza A strains (Influenza virus H9N2 and highly pathogenic H5N1 avian influenza virus), Ebola hemorrhagic fever and severe acute respiratory syndrome (SARS), the actual transmission to humans is a rare event but, once it has occurred, human-to-human transmission maintains the infection cycle for some period of time [8].

Corresponding Author: Endrias Zewdu Gebremedhin, Ambo University, College of Agriculture and Veterinary Sciences, Department of Veterinary Science, P. O. Box 19, Ambo, Ethiopia.

Examples of vector-borne viral zoonotic pathogens include West Nile virus, dengue, chikungunya, Hendra virus (Equine morbilivirus), monkey pox virus and Rift Valley Fever (RVF) [9, 10].

Anthropogenic factors provided rich opportunities for viral pathogens to thrive, prosper and spread. While modern life conditions favor factors responsible for emergence of viral zoonoses more than ever before and are anticipated to be so in the future too [11].

Emerging viral zoonoses affect not only the health of humans, domestic and wild animals but also the economies of nations [12]. These zoonotic diseases also indirectly affect the viability of livestock producers through barriers to trade, the costs associated with control programs, the increased cost of marketing produce to ensure it is safe for human consumption and the loss of markets because of decreased consumer confidence [4]. The health impacts of emerging zoonoses are more important in developing countries than developed nations since they are more likely to establish themselves and cause considerable mortality and morbidity due to inadequate resources, skilled manpower and veterinary and public health infrastructures for early detection and containment [4, 13]. However, the aforementioned factors coupled with underreporting or absence of reporting, misdiagnosis and lack of awareness among the public and health professionals [4] have made estimation of the true burden of emerging zoonoses more difficult in developing countries.

The main objective of this paper was to review available literature on anthropogenic influences leading to the emergence of viral zoonoses.

Historical Phases in the Epidemiological Transitions of Human Emerging Infectious Diseases: Disease emergence *per se* is not a new phenomenon. It is almost certain that disease emergence is a routine event in the evolutionary ecology of pathogens and part of a ubiquitous response of pathogen populations to shifting arrays of host species [7].

In the past history of human infectious diseases there have been major epidemiological transitions associated with changes in human demography, behavior and technology [14, 15]. Anthropogenic factors have always been the driving force behind human epidemiological change and this situation still applies today. The history of human emerging infectious diseases has been described with reference to the following three key transitions [14, 15].

Domestication of Livestock: Domestication of livestock 10,000–15,000 years ago provided multiple opportunities for disease emergence, first by facilitating cross-species (zoonotic) transmission and second by allowing the expansion of human settlements large enough for virulent pathogens, such as measles and smallpox, to persist [16].

Urbanization: As settlements became cities, a second transition point was reached: the problems of sanitation and pest control increased, allowing huge epidemics of infections, such as the Black Death and cholera [7].

Migration, Trade, Exploration and Conquest: Migration, trade, exploration and conquest gave rise to the third major transition in the history of human emerging infectious diseases. This period is the age of discovery/civilization starting from fifteenth century. During these periods human infections established in one area were brought to highly susceptible populations in another, often with catastrophic consequences [7].

It appears that in the era of modern world, mankind is threatened by the appearance of novel diseases and spread of old diseases at an exceptional rate [7].

The Role of Mankind in the Emergence of Viral Zoonoses: Although globalization is essential for trade and economies, it can also have undesirable effect in that it may bring new pathogens and vectors to previously naïve population [17].

Numerous pathogens, hosts and environmental determinants play a role towards emergence of new zoonotic diseases. According to Murphy [18], many factors related to pathogen, host and environment determinants play a role towards the emergence of new zoonotic diseases. Pathogen related determinants include mutation, natural selection and evolutionary progression. Individual host determinants include acquired immunity and physiologic factors while host population determinants are host behavioral characteristics and social, commercial and iatrogenic factors. Environmental determinants include ecologic and climatologic influences [18]. Among the widely cited factors for emergence of viral zoonoses, ecologic and environmental changes (such as economic or agricultural development, change in land use patterns) brought about by human activities are massive [18] and are the leading causes for the emergence of viral zoonoses. These anthropogenic factors include expansion of human population, encroachment on wildlife habitat, change in agricultural practices [12, 17], change in behavior (bush meat consumption, consumption of exotic foods), globalization of trade [12], increased local and international travel, urbanization, deforestation and ecotourism [19-21]. These factors are elaborated in the following section.

Human Population Expansion, Urbanization and Change in Land Use: Humans are important agents of ecological and environmental change. Ecological changes, including those due to agricultural or economic development, are among the most frequently identified factors in emergence of zoonoses. It has been now generally accepted that most drivers of emerging diseases are ecological and the majority of these caused by anthropogenic influences [17, 22-24]. Until recently, majority of the world's population lived in rural areas. In 1800, for example, less than 1.7 percent of people lived in urban communities as compared to 50% in 2007. As a result of population growth, 445 cities reached population levels of over 1 million in 2000 while 25 cities have populations exceeding 11 million people [25]. It has been estimated that by the year 2025, 65% of the world population, including 61% of the population in developing regions, will live in cities [26]. Often, the infrastructure and economy of these large urban areas is insufficient to provide adequate living space, sanitation and clean water for many of the inhabitants. Associated conditions of overcrowding, poor sanitation and degraded environmental conditions facilitate the emergence of various pathogens and disease vectors such as mosquitoes. Under such circumstances, newly introduced infection would have the opportunity to spread in cities [11] and the emergence of dengue fever in the Americas is a good example [25].

Human population in sub-Saharan Africa was doubled between 1975 and 2001 and the African Population and Health Research Center predicts another doubling from 2008 levels to 1.9 billion by 2050. Such rapid population growth and consequent demands for natural resources are making African wild lands increasingly vulnerable to conversion to other land uses, such as logging, agriculture and pasturage [13, 27]. Such human activities disturb the natural ecosystems and can also bring people into new areas while displacing microbes that must then seek out new hosts [10].

Protected areas provide some of the last supplies of ecosystem goods and services for expanding human populations, including firewood, bush meat, clean water, medicinal plants and areas of safety during civil strife. Their porous edges also provide refuge for the vectors of zoonotic disease transmission [13].

The continued increase of global human and animal population and environmental changes has been associated with increased close contact of millions of people with wild and domestic animals [13, 18]. This together with change in land use for livestock and crop production have altered the ecological balance between pathogens and their human and animal hosts [13] thereby accelerating the emergence of new zoonotic pathogens [18].

The concentration of humans in the urban environment due to migration from rural to urban environments and the resettlement of refugees has given rise to mega-cities where a large proportion of persons may live in substandard conditions in marginal areas (“shanty towns”), surrounding the urban core. The crowded living conditions within shanty towns are further degraded by poor sanitation and lack of water; these conditions have been associated with the emergence of diseases, notably those involving vector-transmitted pathogens [28, 29].

Human Encroachment, Habitat Modification, Deforestation, Modern Agricultural Practices and Bush Meat Consumption: A common theme of primary risk factors for the emergence and spread of emerging zoonoses was the increasing demand for animal protein; associated with the expansion and intensification of animal agriculture; long-distance live animal transport, live animal markets, bush meat consumption and habitat destruction [21].

Human population growth and modern agricultural practices have enticed human settlers into clearing patches within ecosystems of maximally high biodiversity, such as tropical rain forests, converting substantial areas into cultivated fields and pastures [30, 31]. In relation of commencement of commercial farming in forest cleared areas dams are built to maintain water for human consumption and for use in irrigated agriculture, but they too may lead to increased zoonotic disease emergence as they provide the milieu for intermingling mosquito vectors and reservoir hosts of arboviruses [17, 32].

Ebola virus infection of humans was first described in Central Africa in 1976. Nowadays, the disease has spread to many African countries including Congo, Gabon, Côte d’Ivoire, Zaire, Sudan, etc. Most epidemics of Ebola hemorrhagic fever in humans has been linked to the handling of gorilla (*Gorilla sp.*), chimpanzee or duiker (*Sylvicapra grimmia*) carcass, themselves incidental victims of infection [8]. Transmission of Ebola virus from

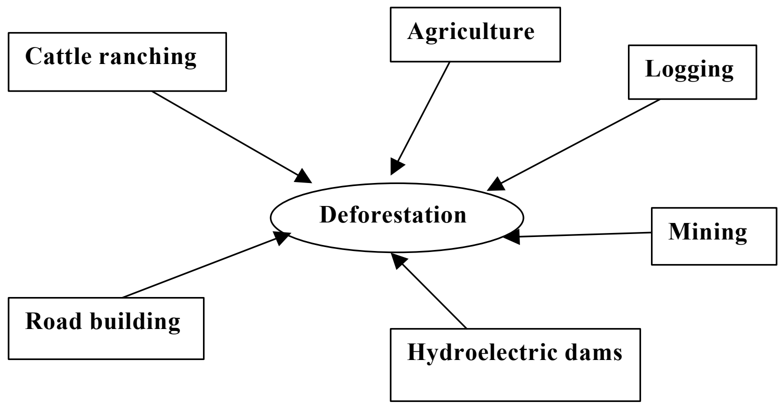

Fig 1: Land use practices and environmental change (adapted from Confalonieria *et al*. [34]

these wild animals to humans (e.g. hunters) was followed by horizontal human-to-human spread infection [8]. Moreover, horizontal transmission of Ebola virus from ape to ape has resulted in the disappearance of several known and well-studied gorilla and chimpanzee groups [8].

Deforestation leads to environmental changes. In recent history, it has been well documented that human encroachment on wildlife habitats has brought marked change in ecology and drastic change in wildlife habitat [12]. The reemergence of human rabies transmitted by vampire bats in Amazon basin leading to the death of 22 people in Brazil and another 14 people in Colombia in 2004 has been linked to anthropogenic activities like deforestation, development of human habitat and mining [33]. Fig. 1 shows land use practices by mankind contributing for deforestation.

In India, deforestation followed by cultivation of rice and human habitat expansion into natural foci of a viral infection has led to epidemics of tick borne viral disease (Kyasanur Forest disease) which claimed life of many people (forest workers) and monkeys. Grazing of cattle in such forest cleared area has favored multiplication of the vector tick called *Haemaphysalis spinigera* [12].

Dam building and reforestation provide examples of landscape changes resulting in the emergence of diseases impacting humans. Mosquito-borne Rift Valley fever (RVF) is primarily a disease of sheep and cattle. This disease had only been known to occur in Africa south of the Sahara. In 1977, following the completion of the Aswan Dam, RVF caused an estimated 200,000 human cases of clinical illness and nearly 600 deaths in Egypt. In 1987, following the completion of the Diama Dam, RVF caused more than 1,200 cases of severe illness and nearly 250 deaths in humans as well as spontaneous abortion in sheep and cattle, in the Senegal River Basin. Sheep and cattle were also affected during both events. In both situations, ecological change in relation to dam construction (i.e., change in the flow of water and formation of pool of water) contributed to the emergence of RVF by providing breeding habitat for the mosquitoes that transmit this disease [25, 35].

Changes in land use commonly are associated with settlement of wild lands or economic development activities. The resulting landscape changes alter the habitat base for vertebrates and invertebrates as well as species interactions [36]. Such changes in land use carry a risk of zoonotic viral disease emergence by affecting infection rate in reservoir hosts [7] a case in point being the emergence of Nipah virus in pig in Malaysia and Hendra virus in horses in Brisbane, Australia. Nipah virus was first reported in pigs and thence humans in Malaysia in 1998. Human cases of Nipah virus infection, apparently unassociated with infection in livestock, have been reported in Bangladesh since 2001. Species of fruit bats (genus *Pteropus*) have been identified as natural hosts of both agents. Anthropogenic changes (habitat loss, hunting) that have impacted the population dynamics of *Pteropus* species across much of their range are hypothesized to have facilitated emergence [37].

Pandemic influenza appears to have an agricultural origin in that its origin is linked to integrated pig-duck farming practiced in China for several centuries, puts these two species in contact and provides a natural laboratory for making new influenza recombinants [11].

Anthropogenic influences in social and ecological situations have led towards the complex evolution of HIV/AIDS in Africa. Although blood banking, the relaxation of sexual mores and injection drug use facilitated the spread of HIV, the simplest and most plausible explanation for the emergence of the virus appears to be exposure to animal blood or excretions as a result of hunting and butchering primates, or the subsequent consumption of uncooked or contaminated bush meat [38]. Human immunodeficiency virus/AIDS is caused by two of the 26 simian immunodeficiency virus (SIV) strains known to occur in African primates. The HIV-1 and HIV-2 viruses have evolved from a chimpanzee (*Pan troglodytes*) strain and a Sooty mangabey (*Cercocebus torquatus*) strain, respectively [39, 40]. Although transmission of SIV strains to humans was a rare event, evidences suggest that initial transmission occurred in equatorial Africa through hunting apes for food which eventually led to high adaptation to humans with subsequent evolvement of contagious human-to-human transmission and maintenance of HIV-1 and HIV-2 independent of their simian origin [8]. HIV infection that has become the biggest zoonotic pandemics in recent human history has claimed the life of millions of people worldwide, the highest death tolls being in Sub-Saharan African countries [8].

Modern transport, Live animal trade, International travel/ Ecotourism: Modern transports enhance social connectivity [41] and circumnavigation of the globe in less than the incubation period of most infectious agents [10]. Modern travel has tremendously increased the number of people travelling internationally every year. About 1 million people travel internationally each day and about 50 million passengers travel annually from developed to developing countries and vice versa [42]. In recent years, favored by the fast modern transport systems ecotourism is expanding. Ecotouristic activities particularly in primitive settings with inadequate hygiene are often linked with the acquisition of zoonotic agents [12]. Many travelers move from place to place or country to country with their pets which might serve as hosts for vectors and infectious pathogens. Thus, international travel and ecotourism are the most influential and certainly the most infamous anthropogenic modifiers driving the emergence of viral zoonoses.

Severe acute respiratory syndrome (SARS) is acute and sometimes life-threatening contagious respiratory disease of humans. SARS emerged in 2002 and 2003 in Southeast Asia [43]. The disease is caused by a novel coronavirus, unrelated to coronaviruses that were commonly associated with human infections, or known to infect livestock. In recent years, the disease has spread from its initial place of origin in China to different countries through international travel. Although the reservoir host of the virus is yet not fully known, epidemiological evidences suggest that there is an association between emergence of SARS and the expanding commercial trade in live wild animals like civets (*Paguma larvata*), or foxes and domestic cats in southern Asia (the virus has been isolated from these animals). Close contact between humans, livestock and wild animals in this region might have favored an ideal setting for the virus to cross the species barrier [8, 43].

The Middle East respiratory syndrome coronavirus (MERS-CoV) is a novel coronavirus (nCoV), closest relative of SARS virus, first reported as a newly emerging viral disease from Saudi Arabia, following the identification of a previously unknown coronavirus from the lungs of a 60-year-old man with pneumonia and acute renal failure [44, 45]. As of 31 October 2013, the World Health Organization confirmed that 149 people have contracted MERS worldwide, of which 63 have died [46].

The epidemiology of the disease so far is suggestive of multiple zoonotic transmissions from an animal reservoir leading to human infection, sometimes with secondary transmission events in humans [47]. The geographical distribution of MERS-CoV and its animal reservoirs are not well defined. Camels (*Camelus dromedarious*) and African and Australian insectivorous bats (*Pipistrellus pipistrellus*) have been suspected as reservoirs following the detection of MERS-CoV antibody in the Arabian Peninsula. Substantial movement of people and livestock across Middle Easter countries [47] and close contact of the victim people with camels (including visibly ill camels) [48] might have favored zoonotic transmission of MERS-CoV from camels to humans [47].

Monkey pox virus, an ortopoxvirus closely related to smallpox normally confined to the African rainforest, was introduced to USA from West Africa (Ghana) in 2003 by a Texas animal dealer who imported a large shipment of Monkeypox virus infected wild–caught animals (rodents). The disease was then spread to prairie dogs and later to humans [18].

Aedes albopictus (the Asian tiger mosquito), a vector of a very serious disease called Eastern equine encephalomyelitis, was introduced into the United States, Brazil and parts of Africa in shipments of used tires from Asia [49].

Climate Change: Global warming, climate change and extreme weather events have an adverse effect on biodiversity distribution of animals and microflora, all of which may increase the likelihood of emergence of zoonotic agents and infectious disease outbreaks [4].

The activities of mankind contribution for climate change are immense. Global climate change is due to the emission of greenhouse gases (CO_2, nitrous oxide and methane) to the atmosphere due to the burning of fossil fuels and deforestation/forest fires [4, 50]. These greenhouse gases traps heat and light from the sun in the earth's atmosphere which increases the temperature [4], decrease in precipitation with eventual global warming [50]. Climate change may increase the likelihood of emergence of zoonotic agents and infectious disease outbreaks in 3 ways:

- Climate change may increase the range or abundance of animal reservoirs or insect vectors.
- Climate change may shorten pathogen development time in vectors leading to increased duration of infectiousness and prolong transmission to humans.
- Climate change may increase the importation of vectors or animal reservoirs (e.g., by boat or air) to new regions, which may cause the establishment of novel imported infectious diseases in regions that were previously unable to support endemic transmission [9].

Scarcity of water in relation to global climate change leads to squeezing of animals and humans into smaller workable areas which in turn brings increased close contact of infected animals and people thereby facilitating disease transmission [13].

The transmission of vector-borne viral zoonoses may also be enhanced by earlier onset of spring, resulting in a prolonged amplification cycle. West Nile virus, which appeared in Canada in 2002, has an amplification cycle that involves mosquitoes and birds. Human infections become more likely as the proportion of "bridge" vectors (mosquitoes that bite both birds and humans) increases. In temperate regions, virus amplification begins with the onset of mosquito activity in spring. Human risk peaks in late summer or early autumn and risk decreases with the disappearance of mosquitoes in autumn [9].

Migrating birds can carry infected ticks or viruses (e.g. West Nile Virus). An increase in winter temperatures improves the chances of animal or bird host survival as well as the survival and replication rate of the many insect vectors which can transmit infectious agents. As the number of hot summer days' increases, infected mosquitoes, horseflies and ticks become more active. As a result, one might expect that more people will get bitten and be potentially exposed to the pathogens carried by these insects and tick [51].

Climate change might lead to flooding which provides breeding habitats for vectors and reservoir hosts, increasing their abundance and geographic range, which may lead to more frequent outbreaks of viral zoonoses [9].

Climate change increases the risk of viral zoonoses by expanding the host, reservoir and vector base [52-54]. Climate change affects directly and indirectly disease vectors particularly mosquitoes. Some viral zoonotic diseases such as rabies, Hantavirus, yellow fever, H1N1 influenza and other viral haemorrhagic fevers have been linked to climate variability and climate change [55]. The intense rainfall and flooding following the droughts, which increases food availability for peri-domestic (living both indoors and outdoors) rodents [56] have been reported for outbreaks of hantavirus pulmonary syndrome in Argentina, Bolivia, Chile, Paraguay, Panama and Brazil. Outbreaks of *Hantavirus* infections [55, 56], West Nile virus, Rift Valley fever and Dengue fever in new geographical areas have been linked with the El Nino oscillation [4].

Vector-borne viral zoonotic diseases such as West Nile virus, dengue fever and Japanese encephalitis, have emerged as a serious public health problem in some countries of South-East Asia possibly as a consequence of climate changes [59] that extend further the range of the mosquitoes spread into new regions.

Climate change may cause increased risk of food contamination, increased environmental survival of pathogens, changes in prevalence of pathogens in animal reservoirs and changes in host–parasite ecology, which may enhance the risk of foodborne disease [9].

The risk of rabies and Kyasanur forest disease may increase due to climate variability which leads to change in the range of area over which wildlife can live thereby increasing the chance of contact between species that have not interacted before [60, 61].

Avian influenza viruses circulate naturally in the form of a gene pool in wild water birds, particularly in migratory ducks, geese and swans. Wild ducks presumably form an important source of virus spill-over to poultry [62]. Highly pathogenic avian influenza is a poultry disease evolving from low pathogenicity avian influenza virus circulating in wild birds and introduced in terrestrial poultry of sufficient flock size or density [62]. Climate change will directly affect the migration cycle of birds. Extreme climatic events may trigger abnormal population movements, as was apparently observed in January 2006 when mute swan populations fled a cold weather spell that hit the eastern Caspian Sea basin, presumably spreading HPAI H5N1 virus towards Western Europe [62]. By changing the distribution, composition and abundance of wild duck populations, climate change will indirectly modify the interface between domestic and wild waterfowl and with it the potential AI virus flow between aquatic and terrestrial poultry. Although wild birds have been implicated in some virus introductions, there is also the consensus view that HPAI H5N1 spreads locally through human related activities, including trade in poultry and poultry products [62].

The upsurge of highly pathogenic avian influenza (HPAI) H5N1 epizootic waves, that killed140 million domestic birds in 2005 and 2006 in Southeast Asia alone, with an estimated economic close to US$10 billion [63] has been linked to changes in agricultural practices, intensification of the poultry sector and globalization of trade in live poultry and poultry products [64]. Changes in agricultural practices have resulted in increasing pressure for agricultural land over natural wetlands and to higher contacts between wild and domestic avifauna [62].

The Miracle of Modern Medicine: Modern medical practices requiring the widespread use of needles, increased application of immunosuppressive therapies, organ transplant and blood transfusions have contributed substantially to the spread and emergence of zoonotic pathogens [65].

Prospective: The magnitude and complexity of emerging zoonoses is likely to continue as a major problem for the foreseeable future so long as human actions contributing for their emergence are not curtailed or prevented. The emerging viral zoonoses discussed in this review are just examples rather than a holistic compendium. Moreover, infection dynamics of emerging viral zoonoses in animal host population in general and in wildlife hosts in particular is still little known [66]. This is particularly true in developing countries where many people live in remote settlements with limited access to medical and public health services leading to failure to detect many infectious diseases and underestimation of the true rate of infection [51]. Epidemiology of multi-host viral pathogens is often complex and identification of reservoirs of viral infections is often challenging task [66]. Nevertheless, previous reports have clearly documented that emerging zoonoses affect humans, domestic animals and wildlife worldwide. The emergence and re-emergence of some new viruses pose major global threat to human health and sustainable development [67].

Evidences of the past indicate that diseases have no border and many pathogens, particularly viral pathogens, have the potential to emerge whenever favorable ecological and environmental conditions for cross-species transmission are created. Environmental stress affecting living organisms in diverse ecologies is likely to intensify with increasing human population and consequent societal needs (living space, food, water, recreation opportunities and sustained economic growth) [36]. As a result, list of pathogens causing emerging zoonoses will continue to grow [66]. The emergence of molecular diagnostic methods for detection and identification of emerging pathogens, especially those which are non cultivable, have become very useful in recognizing newly emerging as well previously existing pathogens unknown by mankind. The sudden appearance of emerging zoonotic diseases outbreaks has entailed huge challenge to humans and animals in the past and might continue to do so in the future unless mechanisms of prevention and control are in place.

Emerging viral zoonotic diseases are usually double burden diseases with complex consequences. Despite the enormous scientific progress in the 21th Century, emerging viral zoonotic diseases still cause enormous losses globally. In developing countries emerging zoonoses certainly impede the social and economic development of nations through depletion of the scarce resources. Moreover, emerging diseases affecting wildlife are also of significant threats to conservation. Prevention and control emerging viral zoonoses require unique strategies, apart from traditional approaches [67]. In order to counter the burden of emerging zoonoses in general and that of emerging viral zoonoses in particular, the following points are of paramount importance for rapid detection and identification of factors/ processes driving cross-species pathogen transmission so as to provide rapid, reliable and effective responses for prevention and control in both the veterinary and public health sectors.

- Identification of major gaps in the area of surveillance, research and training programs and the availability of qualified professionals in different fields.
- Political commitment for sustained investment for:
  - Building of robust health infrastructures at regional and federal level and strengthening the existing ones.
  - Human capacity building and continued development of professionals at different level is a key point towards the fight against newly

emerging zoonotic diseases. The predominance of viral pathogens among causes of emerging zoonotic diseases in humans and animals highlights the need for training as well as maintaining expertise in virological techniques, for improved anti-viral treatments and for enhanced collaboration between medical and veterinary virologists.

- Increased and sustained surveillance of emerging zoonoses and integration of the activities across human, domestic animal and wildlife populations. To this end, establishment of a strategic centre for collaborative multidisciplinary professional (medical, veterinary, laboratory, public health, etc.) work under the concept of 'one medicine" or "one health" is important because along the increasing trend of human population there will be more direct and indirect contact among humans, domestic animals and wildlife. Thus, there is a strong need to generate new knowledge by the joint efforts of multidisciplinary professionals crucial towards prevention and control of emerging zoonoses.
- Establishment of effective networking and coordination system among epidemiological and laboratory units under public health and animal health sectors as well as among stakeholders (government, international agencies, etc.) at different level (regional, national, global) is imperative.
- Strengthening of disease reporting systems in animals and humans; and use of modern information communication technologies for local, regional and international sharing of information is crucial.
- In the globalized and changing world the scientific community should think research beyond traditional disease research, consider research of emerging zoonoses from the global perspective and pay due attention to anthropogenic influences as researchable agendas. Therefore, research as well as investigation of outbreak of emerging zoonotic diseases should be approached from multidisciplinary perspectives so as to include humans, domestic animals, wildlife, sea animals etc.
- Formulation and effective implementation of appropriate environmental, agricultural, energy and economic policies are necessary to control emerging infectious diseases in a sustainable manner.
- Physicians, veterinarians and other allied health professionals should be actively involved in public education programs about sources (including pet ownership and wild animal adoption), mode of transmission, economic impacts, health burdens, prevention and control of emerging viral zoonoses.
- There is an urgent need to modify medical and veterinary curricula so that aspects of zoonoses (epidemiology, ecology, public health, etc.) are adequately addressed.

REFERENCES

1. Chomel, B.B., 1998. New emerging zoonoses: a challenge and an opportunity for the veterinary profession. Comparative Immunology, Microbiology and Infectious Diseases, 21: 1-14.
2. Taylor, L.H., S.M. Latham and M.E. Woolhouse, 2001. Risk factors for human disease emergence. Philosophical Transactions of the Royal Society of London B. Biological Sciences, 356: 983-989.
3. Daszak, P., A.A. Cunningham and A.D. Hyatt, 2000. Emerging infectious diseases of wildlife- threats to biodiversity and human health. Science, 287: 443-449.
4. Sachan, N. and V.P. Singh, 2010. Effect of climatic changes on the prevalence of zoonotic diseases. Veterinary World, 3(11): 519-522.
5. WHO (World Health Organization), 1959. Zoonoses: second report of the joint WHO/FAO expert committee.
6. Palmer, S.R., E.J.L. Soulsby and D.I.H. Simpson, 1998. Zoonoses: Biology clinical practice and public health control. Oxford University Press, New York.
7. Cleaveland, S., D.T. Haydon and L. Taylor, 2007. Overviews of pathogen emergence: Which pathogens emerge, when and why? Current Topics in Microbiology and Immunology, 315: 85-111.
8. Bengis, R.G., F.A. Leighton, J.R. Fischer, M. Artois, T. Mörner and C.M. Tate, 2004. The role of wildlife in emerging and re-emerging zoonoses. Review of scientific tech. Office des international Epizootics, 23(2): 497-511.
9. Greer, A., N.G. Victoria and F. David, 2008. Climate change and infectious diseases in North America: the road ahead. Canadian Medical Association Journal, 178(6): 715-722.
10. Zowghi, E., 2008. Emerging and re-emerging zoonoses. Iranian Journal of Clinical Infectious Diseases, 3(2): 109-115.
11. Morse, S.S., 1995. Factors in the Emergence of Infectious Diseases. Emerging Infectious Diseases, 1(1): 1-15.

12. Chomel, B.B., A. Belotto and F.X. Meslin, 2007. Wildlife, exotic pets and emerging zoonoses. Emerging Infectious Diseases, 13(1): 1-6.
13. Mazet, J.A.K., D.L. Clifford, P.B. Coppolillo, A.B. Deolalikar, J.D. Erickson and R.R. Kazwala, 2009. A ‘‘One Health’’ approach to address emerging zoonoses: The HALI project in Tanzania. PLoS Medicine, 6(12): e1000190. doi: 10.1371/ journal.pmed.1000190.
14. Barrett, R., C.W. Kuzawa, T. McDade and G.J. Armelagos, 1998. Emerging and re-emerging infectious diseases: the third epidemiologic transition. Annual Review of Anthropology, 27: 247-271.
15. McMichael, A.J., 2004. Environmental and social influences on emerging infectious diseases: past, present and future. Philosophical Transactions of the Royal Society of London B Biological Sciences, 359: 1049-1058.
16. Diamond, J., 2002. Evolution, consequences and future of plant and animal domestication. Nature, 418: 700-707.
17. Lindahl, F.J. and D. Grace, 2015. The consequences of human actions on risks for infectious diseases: a review Infection Ecology and Epidemiology, 5: 30048- http://dx.doi.org/10.3402/iee.v5.30048.
18. Murphy, F.A., 1998. Emerging zoonoses. Emerging Infectious Diseases, 4(3): 429-435.
19. Grmek, M.D., 1993. History of AIDS: emergence and origin of a modern pandemic. Princeton University Press, Princeton, New Jersey, pp: 290.
20. Barnett, T. and A. Whiteside, 2002. AIDS in the twenty-first century: disease and globalization. Palgrave MacMillan, New York, pp: 432.
21. Greger, M., 2007. The Human/animal interface: Emergence and resurgence of zoonotic infectious diseases. Critical Reviews in Microbiology, 33: 243-299.
22. Morse, S.S. and A. Schluederberg, 1990. Emerging viruses: the evolution of viruses and viral diseases. Journal of Infectious Disease, 162: 17.
23. Daszak, P., A.A. Cunningham and A.D. Hyatt, 2001. Anthropogenic environmental change and the emergence of infectious diseases in wildlife. Acta Tropica, 78: 103-116.
24. Gould, E.A., S. Higgs, A. Buckley and T.S. Gritsun, 2006. Potential arbovirus emergence and implications for the United Kingdom. Emerging Infectious Disease, 12: 549-555.
25. Lederberg, J., R.E. Shope and S.C. Oaks, 1992, Emerging infections: microbial threats to health in the United States: Institute of Medicine, Washington, D.C., National Academy Press, pp: 294.
26. United Nations, 1991. World urbanization prospects, 1990. New York: United Nations.
27. Newark, W.D., 2008. Isolation of African protected areas. Frontiers in Ecology and The Environment, 6: 321-328.
28. Gubler, D.J., 2002. The global emergence/resurgence of arboviral diseases as public health problems. Archives of Medical Research, 33: 330-342.
29. Mackenzie, J.S., D.J. Gubler and L.R. Petersen, 2004. Emerging flaviviruses: the spread and resurgence of dengue Japanese encephalitis and West Nile viruses. Nature Medicine, 10: S98-S109.
30. Patz, J.A., P. Daszak, G.M. Tabor, A.A. Aguirre, M. Pearl, J. Epstein, N.D. Wolfe, A.M. Kilpatrick, J. Foufopoulos, D. Molyneux and D.J. Bradley, 2004. Unhealthy landscapes: Policy recommendations on land use change and infectious disease emergence. Environmental Health Perspectives, 112: 1092-1098.
31. LoGiudice, K., R.S. Ostfeld, K.A. Schmidt and F. Keesing, 2003. The ecology of infectious disease: effects of host diversity and community composition on Lyme disease risk. Proceedings of the National Academy of Sciences USA, 100: 567-571.
32. Jones, B.A., D. Grace, R. Kock, S. Alonso, J. Rushton, M.Y., Said, D. McKeever, F. Mutua, J. Young, J. McDermott and D.U. Pfeiffer, 2013. Zoonosis emergence linked to agricultural intensification and environmental change. Proceedings of the National Academy of Sciences USA, 110(21): 8399-8404.
33. Schneider, M.C., A. Belotto, M.P. Adé, O.P.S. Unidad de Salud Pública Veterinaria, L.F. Leanes, E. Correa, O.P.S. Centro Panamericano de Fiebre Aftosa (PANAFTOSA), H. Tamayo. O.P.S. Representación en Perú, G. Medina, M.J. Rodrigues and O.P.S. Consultores, 2005. Epidemiologic situation of human rabies in Latin America in 2004. Epidemiological Bulletin/ PAHO, 26: 2-4.
34. Confalonieria, U.E.C., C. Margonaria and A.F. Quintão, 2014. Environmental change and the dynamics of parasitic diseases in the Amazon. Acta Tropica, 129: 33- 41.

35. Anonymous, 1997. The urban environment. World resources institute, UNEP, UNDP and World Bank. World resources 1996-97, 1-8 Nov., p:1-3. Available online: http://www.eurosurveillance.org/ViewArticle.aspx?ArticleId=20574.
36. Friend, M., 2006, Disease Emergence and Resurgence: The Wildlife-Human Connection: Reston, Va., U.S. Geological Survey, Circular, 1285: 400.
37. Field, H.E., J.S. Mackenzie and P. Daszak, 2007. Henipaviruses: Emerging Paramyxoviruses Associated with Fruit Bats. Current Topics in Microbiology and Immunology, 315: 133-159.
38. Sharp, P.M., E. Bailes, R.R. Chaudhuri, C.M. Rodenburg, M.O. Santiago and B.H. Hahn, 2001. The origins of acquired immune deficiency syndrome viruses: Where and when? Philosophical Transactions of the Royal Society of London B. Biological Sciences, 356: 867-876.
39. Mahy, B.W.J. and F.A. Murphy, 1998. Emergence and reemergence of viral infections. In: Topley and Wilson's microbiology and microbial infections, Vol. 1, 9th ed. (Eds., Mahy, B.W.J. and L. Collier). Edward Arnold, London, pp: 1011-1025.
40. Hahn, B.H., G.M. Shaw, K.M. De Cock and P.M. Sharp, 2000. AIDS as a zoonosis: scientific and public health implications. Science, 287(5453): 607-614.
41. Larkin, M., 2000. Hunting and logging linked to emerging infectious diseases. Lancet, 356: 1173.
42. Harrus, S. and G. Baneth, 2005. Drivers for the emergence and re-emergence of vector-borne protozoal and bacterial diseases. International Journal for Parasitology, 35: 1309-1318.
43. Xu, R.H., J.F. He, M.R. Evans, G.W. Peng, H.E. Field, D.W. Yu, C.K. Lee, H.M. Luo, W.S. Lin, P. Lin, L.H. Li, W.J. Liang, J.H. Lin and A. Schnur, 2004. Epidemiologic clues to SARS origin in China. Emerging Infectious Disease, 10(6): 1030-1037.
44. Miriam, F., 2012. New SARS-like virus poses medical mystery. CNN. http:// thechart.blogs.cnn.com/ 2012/09/24/new-sars-like-virus-poses-medical-mystery/ accessed 22 September 2018.
45. Zaki, A.M., S. van Boheemen, T.M. Bestebroer, A.D. Osterhaus and R.A. Fouchier, 2012. Isolation of a novel coronavirus from a man with pneumonia in Saudi Arabia. New England Journal of Medicine, 367(19): 1814-1820.
46. Kelland, K., 2013. WHO confirms four more cases of Middle East Virus (in English). Reuters. http://english.ahram.org.eg/News/85288.aspx, Retrieved 31 Dec 2018.
47. Perera, R.A., P. Wang, M.R. Gomaa, R. El-Shesheny, A. Kandeil, O. Bagato, L.Y. Siu, M.M. Shehata, A.S. Kayed, Y. Moatasim, M. Li, L.L. Poon, Y. Guan, R.J. Webby, M.A. Ali, J.S. Peiris and G. Kayali, 2013. Seroepidemiology for MERS coronavirus using microneutralization and pseudoparticle virus neutralization assays reveal a high prevalence of antibody in dromedary camels in Egypt. EuroSurveillance, 18 (36): pii=20574. http:// www.eurosurveillance.org/ ViewArticle.aspx? ArticleId=20574.
48. McNeil Jr, D.G., 2013. Camels linked to spread of fatal virus. The New York Times. https:// www.nytimes.com/ 2014/02/ 25/health/camels-linked-to-spread-of-deadly-virus-in-people.html, accessed September 20, 2018.
49. CDC (Centers for Disease Control and Prevention), 1991. *Aedes albopictus* introduction into continental Africa. Morbidity and Mortality Weekly Report, 40: 836-838.
50. IPCC, 2007. Climate change 2007: mitigation of climate change: contribution of Working group III to the Fourth assessment report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University.
51. Revich, B., N. Tokarevich and A.J. Parkinson, 2012. Climate change and zoonotic infections in the Russian Arctic. International Journal of Circumpolar Health, 71: 18792. http:// dx.doi.org/ 10.3402/ ijch.v71i0.18792.
52. Singh, B.B., R. Sharma, J.P.S. Gill, R.S. Aulakh and H.S. Banga, 2011. Climate change, zoonoses and India. Scientific and Technical Review of the Office International des Epizooties, 30(3): 779-788.
53. Birhan, G., A. Alebie, B. Admassu, A. Shite, S. Mohamed and B. Dagnaw, 2015. A review on emerging and re-emerging viral zoonotic diseases. International Journal of Basic and Applied Virology, 4(2): 53-59.
54. Abdela, N. and K. Jilo, 2016. Impact of Climate Change on Livestock Health: A Review. Global Veterinaria, 16(5): 419-424.

55. Rodríguez-Morales, A.J. and C.A. Delgado-López, 2012. Chapter 13. Impact of Climate Change on Zoonotic Diseases in Latin America. In: Chhetri, N. (Ed.) Earth and Planetary Sciences "Human and Social Dimensions of Climate Change", Published: November 14, 2012 under CC BY 3.0 license http://dx.doi.org/10.5772/50605, DOI: 10.5772/50605 accessed on October 12, 2018.
56. Magrin, G., C. Gay Garcia, D. Cruz Choque, J.C. Giménez, A.R. Moreno, G.J. Nagy, C. Nobre and A. Villamizar, 2007. Chapter 13 - Latin America in Parry, Martin, Osvaldo Canziani, Jean Palutikof, Paul van der Linden and Clair Hanson (editors) Climate Change 2007: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge and New York, pp: 581-615.
57. Hjelle, B. and G.E. Glass, 2000. Outbreak of Hantavirus infection in the four corners region of the United States in the wake of the 1997-1998 El Niño-southern oscillation. Journal of Infectious Diseases, 181(5): 1569-1573.
58. Glass, G.E., T.L. Yates, J.B. Fine, T.M. Shields, J.B. Kendall, A.G. Hope, C.A. Parmenter, C.J. Peters, T.G. Ksiazek, C.S Li, J.A. Patz and J.N. Mills, 2002. Satellite imagery characterizes local animal reservoir populations of Sin Nombre virus in the southwestern United States. Proceedings of the National Academy of Sciences USA, 99(26): 16817-16822.
59. Reiter, P., 2001. Climate change and mosquito-borne disease. Environmental Health Perspectives, 109(1): 141-161.
60. Pattnaik, P., 2006. Kyasanur forest disease: an epidemiological view in India. Reviews in Medical Virology, 16(3): 151-165.
61. Rozario, M., 2008. Rabies in India. Canadian Medical Association Journal, 178(5): 564-566.
62. Gilbert, M., J. Slingenbergh and X. Xiao, 2008. Climate change and avian influenza. Scientific and Technical Review of the Office International des Epizooties, 27(2): 459-466.
63. FAO/OIE (Food and Agriculture Organization of the United Nations (FAO)/World Organization for Animal Health (OIE)), 2005. A global strategy for the progressive control of highly pathogenic avian influenza (HPAI). FAO, Rome, OIE, Paris, World Health Organization, Geneva.
64. Slingenbergh, J., M. Gilbert, K. DeBalogh, W. Wint and L.J. King, 2004. Ecological sources of zoonotic diseases. In emerging zoonoses and pathogens of public health concern. Scientific and Technical Review of the Office International des Epizooties, 23(2): 467-484.
65. Institute of Medicine, 2003. Microbial threats to health; emergence, detection and response. National Academies Press, Washington, DC.
66. Haydon, D.T., S. Cleaveland, L.H. Taylor and M.K. Laurenson, 2002. Identifying reservoirs of infection: a conceptual and practical challenge. Emerging Infectious Disease, 8: 1468-1473.
67. Dulo, F. and M. Pal, 2017. Emerging viral zoonoses and their implications on public health. World Applied Sciences Journal, 35(2): 188-198.