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A Review On Driving Factors Of Emerging And Re-Emerging Zoonoses

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Abstract: The occurrence of emerging and re-emerging zoonotic diseases over the past few years is a matter of concern and is likely to increase in the near future. This is due to a number of factors and driving forces that have a potential to create a new era of emerging and re-emerging zoonotic diseases. These factors are complicated and the complex nature of the human animal interface is constantly influenced by the effects of climate change, anthropogenic and natural factors. Change in ecosystem, microbial adaptation, climate and weather change, Lack of adequate food safety, international travel and commerce, animal migration, increased human-animal interface, human demographic and behavioral factors, technology and industry, bush meat hunting, and keeping pets are among the most common factors that contribute for the occurrence of emerging and re-emerging zoonotic diseases. Microbial evolution is the intrinsic factor that leads to the emergence of new pathogens, while social and environmental factors are external factors. Although, all the factors mentioned above have a significant impact on emerging and re-emerging zoonotic diseases, climate change play a unique worldwide effect especially on most vector-borne and water-borne zoonoses. This is because they are very sensitive to climate change such as temperature, humidity, and precipitation. Even though, the extent varies all these factors play a great role in the occurrence of emerging and re-emerging zoonoses in different ways. Now a day, there is a great possibility for emerging and re-emerging zoonoses to be happening since all these driving forces are circulating and increasing from time to time due to increased human population and need. So it may result in a significant public health impact globally because no one knows what new diseases will emerge and what old ones will re-emerge. For those reasons, this review is to give an overview of the factors that potentially contribute to the occurrence of emerging and re-emerging zoonotic diseases, and to create awareness to the community on the ongoing climate change by indicating the link between climate change and the occurrence of emerging and re-emerging zoonoses since it will be a burning issue in the feature unless appropriate measure is not taken.

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1. Introduction

A zoonotic disease is any disease which transmitted from vertebrate animals to man under natural condition (WHO, 2010). An emerging infection is one that is newly recognized, newly appearing in a different population than previously affected, newly affecting much more individuals, or has evolved new attributes (Fineberg and Wilson, 2010). Of the total of 1415 microbial diseases affecting humans, 61% are zoonotic and among emerging infectious diseases, 75% are zoonotic with wildlife being one of the major sources of infection (Venkatesan *et al*., 2010).

The probability of occurring emerging and re-emerging zoonoses are increasing due to several critical factors that cause emerging and re-emerging viral zoonoses. These factors consist of microbial adaptation, climate and weather change, changing the ecosystems, human demographic and behavioral factors, animal migration, wildlife, economic development and land use, international travel, and commerce, bushmeat hunting, keeping animals as pet, technology, and industry (Hamburgm, and Lederberg, 2003). The Re-emergence and increase of zoonotic viral diseases are also a consequence of anthropogenic environmental changes, such as distortion of the ecological balances and changes in agriculture (Manojkumar and Mrudula, 2006).

Interactions at the animal-human interface are increasingly recognized as the source for potential epidemics and the generation of novel pathogens (Cutler *et al*., 2010). This interaction between ecology influences the emergence and re-emergence of zoonotic viral disease (Venkatesan *et al*., 2010). Since microbes continue to evolve and adapt with the tremendous acceleration and expansion of global trade, human movement, travel and the burgeoning globally. Microbes have an even greater opportunity to adapt, change and be transported to new hosts and ecosystems, often with the catastrophic result (King, 2004).

Emergence of new zoonotic pathogens seems to be accelerating as a result of global human and livestock animal populations have continued to grow, bringing increasingly larger numbers of people and animals into close contact; transportation has advanced, making it possible to circumnavigate the globe in less than the incubation period of most infectious agents; ecologic and environmental changes brought about by human activity are massive; and bioterroristic activities, supported by rogue governments as well as organized amateurs are increasing, and in most instances the infectious agents of choice seem to be zoonotic (Murphy, 1998).

Although the spread of diseases is multi-causal, global climate change may be a significant contributor because weather and climate can influence host defenses, vectors, pathogens and habitats (Lonnie, 2004). Analyses on emerging infectious diseases also show that anthropogenic factors including land use change such as deforestation, mining and oil extraction, food production changes, global trade and travel are among the leading causes of disease emergence (Karesh *et al*., 2012).

Emerging and re-emerging zoonotic diseases result in a significant human morbidity and mortality mainly in poor and marginalized communities since these diseases are massively misdiagnosed and underreported (WHO, 2010). Given that all these driving forces are going up, which lead to the increase in the likelihood of the occurrence of emerging and re-emerging zoonoses. Especially the effect of anthropogenic activities that cause the change in the ecosystem and climate is increasing and the risk may be vast in the near future due to lack of attention for these catastrophic activities.

Therefore, the objectives of this seminar paper are:

- To review on the impact of climate change, and
- To highlight other factors those contribute for the occurrence of emerging and re-emerging zoonotic diseases.

2. Emerging And Re-Emerging Zoonoses

Emerging zoonotic infectious diseases are those infections, in which the incidence of humans and animal have either increased during the last two decades or threaten to increase in the near future. This term includes newly appearing infections or those spreading to new geographical areas. It also refers to those diseases, which were easily controlled previously by antimicrobials but have developed new resistance to different drugs whereas re-emerging infectious diseases are those that have reappeared after a significant decline in their incidence (Alula, 2012).

Zoonotic disease emergence often occurs in stages, with an initial series of spillover events, followed by repeated small outbreaks in people, and then pathogen adaptation for a human to human transmission. Each stage might have a different driver, and therefore a different control measure. For example, Human immunodeficiency virus-1 emerged from chimpanzees in Africa, spilling over to humans repeatedly before its global spread (Hahn *et al*., 2000).

Nipah virus is another example of a recently discovered *paramyxovirus* with fruit bat reservoir hosts. It caused a large-scale outbreak in Malaysian pig farmers in 1998. It is a growing threat due to its broad host range, wide geographical distribution, high case fatality, reports of human to human transmission, and the lack of vaccines or effective therapies (Eaton *et al*., 2006; Gurley *et al*., 2007). Analysis of food animal production data from the index site a commercial pig farm in Malaysia before and during the outbreak shows that the emergence was likely caused by repeated introduction of *Nipah virus* from the wildlife reservoir into an intensively managed, commercial pig population site planted with mango trees (Daszak *et al*., 2006). This repeated introduction lead to changes in infection dynamics in the pigs and a long term, within farm persistence of virus that would otherwise have died out. This causative mechanism has been previously proposed as a driver of Highly Pathogenic Avian Influenza H_5N_1 dynamics in poultry and the emergence of other pathogens (Pulliam *et al*., 2007).

3. Impact Of Climate Change On Emerging And Re-Emerging Zoonoses

Global temperatures are rising at an unprecedented rate and this is mostly attributed to the anthropogenic emission of greenhouse gasses. Temperature increases of 0.2°C per decade have been projected with a predicted mean temperature rise ranging between 1.8°C and 4°C by the end of the 21st century (IPCC, 2007). The influence of geo climatic change on zoonotic disease epidemiology is evident by changes in a reservoir and vector dynamics. Climatic variation creates new ecological niches for vectors hence altering the temporal and spatial distribution of disease (Lafferty, 2009). The increased temperature can enhance pathogen development, disease transmission, and host susceptibility (Harvell *et al*., 2002). Water-borne infectious diseases are also strongly affected by climate change. During times of drought, water scarcity results in poor sanitation; therefore, many people can be exposed to potentially contaminated water (Auld *et al*., 2004; Charron *et al*., 2004).

Although the spread of disease is multi-causal, global climate change may be a significant contributor. Weather and climate can influence host defenses, vectors, pathogens and habitats (Lonnie, 2004). Vector-borne and water-borne diseases are both strongly affected by climate. Since arthropod vectors tend to be most active at high temperatures and because water scarcity during droughts often leads to poor sanitation, climate change can be expected to drive the spread of vector-borne diseases and diarrhoeal illnesses (Richard *et al*., 2011).

Climate models for greenhouse warming predict that geographic changes will take place in a number of water-borne and vector-borne diseases. These changes will be driven largely by increases in precipitation leading to favorable habitat availability for vectors, intermediate and reservoir hosts, or warming that leads to expansion of ranges in low latitudes, oceans, or mountain regions. Two phenomena indicate that climate change will likely have a heightened impact on key human diseases. First, a strong link exists between El Nino-Southern Oscillation (ENSO) and outbreaks of RVF, cholera, *Hantavirus*, and a range of emergent diseases (Linthicum *et al*., 1999; Anyamba *et al*., 2009). If ENSO cycles become more intense, as they are predicted to do under climate change scenarios, these events may become more extensive and have a greater impact. Secondly, a recent expansion of *Culicoides* species, the vector species that spreads the diseases bluetongue and African Horse Sickness, into Northern Europe, has led to outbreaks of bluetongue there as recently as 2006 and has put Europe on alert for the potential introduction of African Horse Sickness. The recent geographic expansion of this vector species has been hypothesized to have a climate change link, although this remains a controversial point (Purse *et al*., 2005; Wilson *et al*., 2008).

3.1. Impact of climate change on vector borne diseases

Survival and reproduction rate of the vector, time of year and level of vector activity, specifically the biting rate and rate of development and reproduction of the pathogen within the vector are important properties in the transmission of vector-borne diseases. Vectors, pathogens and hosts each survive and reproduce within certain optimal climatic conditions and changes in these conditions can modify greatly these properties of disease transmission. The most influential climatic factors for vector-borne diseases include temperature and precipitation but sea level elevation, the wind, and daylight duration are additional important considerations (Kovats *et al*., 2001). Rainfall patterns can influence the transport and dissemination of infectious agents while temperature can affect their growth and survival (Rose *et al*., 2001).

3.1.1. Temperature and precipitation sensitivity of vector borne diseases

Arthropod vectors such as mosquitoes, ticks, and sandflies are the most sensitive to temperature variability. They are ectothermic and have life cycles that are dependent on ambient temperatures. Disease transmission is likely to occur if there are changes in the extremes of temperature (14-18°C at the lower end and 35-40°C at the upper end). Vector densities are expected to be their greatest at 30-32°C (Githeko *et al*., 2000). Temperature has a direct effect on mosquitoes. It leads to increased activity, increased reproduction and therefore increased the frequency of blood meals and faster digestion of blood (Martin *et al*., 2008). Pathogens harbored by mosquitoes also mature faster. Increased water temperature causes mosquito larvae to develop faster and also increasing overall vector capacity (Reiter, 2008). Extreme temperatures often are lethal to the survival of disease causing pathogens, but incremental changes in the temperature may exert varying effects. Where a vector lives in an environment where the mean temperature approaches the limit of physiological tolerance for the pathogen, a small increase in temperature may be lethal to the pathogen. Alternatively, where a vector lives in an environment of low mean temperature, a small increase in temperature may result in increased development, incubation and replication of the pathogen (Lindsay and Birley, 1996).

The temperature may modify the growth of disease carrying vectors by altering their biting rates, as well as affect vector population dynamics and alter the rate at which they come into contact with humans. Finally, a shift in temperature regime can alter the length of the transmission season (Gubler *et al*., 2001). Disease carrying vectors may adapt to changes in temperature by changing geographical distribution. Another possibility is that vectors undergo an evolutionary response to adapt to increasing temperatures (Bradshaw and Holzapfel, 2001).

Variability in precipitation may have direct consequences on infectious disease outbreaks. Increased precipitation may increase the presence of disease vectors by expanding the size of existent larval habitat and creating new breeding grounds. In addition, increased precipitation may support a growth in food supplies which in turn support a greater population of vertebrate reservoirs. Unseasonable heavy rainfalls may cause flooding and decrease vector populations by eliminating larval habitats and creating unsuitable environments for vertebrate reservoirs (Ko *et al*., 1999).

Alternatively, flooding may force insect or rodent vectors to seek refuge in houses and increase the likelihood of vector-human contact. Epidemics of leptospirosis, a rodent-borne disease, have been documented following severe flooding in Brazil (Ko *et al*., 1999). In the wet tropics, unseasonable drought can cause rivers to slow, creating more stagnant pools that are ideal vector breeding habitats. In general, increased precipitation creates more potential breeding sites for mosquitoes which lead dense vegetation after rainfalls and this provides shelter and resting grounds for vectors (Githeko *et al*., 2000).

3.1.2. Humidity and Sea level sensitivity of vector borne diseases

Humidity can greatly influence transmission of vector borne diseases, particularly for insect vectors. Mosquitoes and ticks can desiccate easily and survival decreases under dry conditions. Saturation deficit (similar to relative humidity) has been found to be one of the most critical determinants in climate/disease models, for example, dengue fever (Focks *et al*., 1995; Hales *et al*., 2002).

The projected rise in sea level associated with climate change is likely to decrease or eliminate breeding habitats for salt marsh mosquitoes. Bird and mammalian hosts that occupy this ecological niche may be threatened by extinction, which would also aid the elimination of viruses endemic to this habitat. Alternatively, inland intrusion of salt water may turn former freshwater habitats into salt marsh areas which could support vector and host species displaced from former salt marsh habitats (Reeves *et al.,* 1994).

3.1.3. Temperature and precipitation sensitivity of water borne diseases

Increasing temperatures may lengthen the seasonality or alter the geographical distribution of water-borne diseases. In the marine environment, warm temperatures create favorable conditions for red tides (blooms of toxic algae) which can increase the incidence of shellfish poisoning (Epstein, 1993). Increasing sea surface temperatures can indirectly influence the viability of enteric pathogens such as *Vibrio cholerae* by increasing their reservoir's food supply (Colwell, 1996). Ambient air temperatures also have been linked to hospital admissions of Peruvian children with diarrhoeal disease (Checkley *et al*., 2000). As a consequence of rising sea temperatures, melting of polar ice caps and glaciers, increase in sea levels is also of concern. Rising sea levels will lead to coastal flooding and risks for water-borne zoonoses. Carbon uptake by the oceans leads to a decrease in pH and marine ecosystems are being threatened (IPCC, 2007).

Heavy rains can contaminate water sheds by transporting human and animal faecal products and other wastes in the groundwater. Evidence of water contamination following heavy rains has been documented for cryptosporidium, and *E.coli* (Parmenter *et al*., 1999). This type of event may be increased in conditions of high soil saturation due to more efficient microbial transport (Rose *et al*., 2001).

3.1.4. Extreme weather events

The El Nino Southern Oscillation (ENSO) cycle is a global climatic phenomenon consisting of hot and warm phases and contributing to increased extreme weather events (Kovats *et al*., 2003). The ENSO has contributed to heavy rain falls and Rift Valley Fever outbreaks in East Africa (Gould and Higgs, 2009). However, the impact of global warming on the ENSO is as yet unknown (McPhaden *et al*., 2006).

3.2. Emerging zoonotic diseases affected by climate change

3.2.1. Chikungunya virus

Climate changes favored the exposure of *Chikungunya virus* (CHIKV) due to increased population of the mosquito vectors and consequently facilitated *CHIKV* emergence in some geographical areas (Patz *et al*., 2005; Chretien *et al*., 2007). The virus, usually transmitted by *Aedes aegypti* mosquitoes, has now repeatedly been associated with a new vector, *Ades Albopictus* (de Lamballerie *et al*., 2008). A notable recent example is the *chikungunya virus* epidemic that swept through the Indian Ocean region beginning in 2006 and which is believed to have infected greater than 2 million people. *Chikungunya virus* infections occurred in Kuala Lumpur, Malaysia in 1998. The first sporadic outbreak of *chikungunya virus* (CHIKV) infection occurred between late 1998 and early 1999 in Port Klang, Kuala Lumpur. *Chikungunya virus* is endemic (Lam *et al*., 2001) may play a substantial role in the spread of the virus to humans, although the effect of a warmer climate has also been reported (Rogers and Randolph, 2003).

Chikungunya disease outbreak occurred in Italy in late summer 2007 where favorable climate condition for virus replication resulted in 200 cases in there. Asian tiger mosquitoes (*Ades albopictus*) are now established in Southern Europe and are better adapted to lower temperatures than the primary vector (*Ades aegypti*) of the *Chikungunya* and *dengue viruses* (Woolhouse and Gaunt, 2007).

3.2.2. Dengue fever virus

Dengue viruses are transmitted and replicate by mosquitoes. Increased warming temperature at night is especially favorable to *Ades aegypti* while *Ades albopictus* has been permitted to withstand at the freezing condition. The northern form of the mosquito is triggered by shortened periods of sunlight to enter diapauses, a physiological state of the egg that makes the egg resist cold temperature and delays hatching until the spring. Thus, the mosquito is able to survive freezing (Chunsuttiwat, 2001). Humidity can greatly influence transmission of vector borne diseases, particularly for insect vectors. Mosquitoes and ticks can desiccate easily and survival decreases under dry conditions. Saturation deficit has been found to be one of the most critical determinants in climate disease models, for example, dengue fever (Hales *et al*., 2002). The potential for vector-borne zoonotic transmission to adapt to vector borne human to human transmission is exemplified historically by dengue virus and Plasmodium species, and more recently by *Zika virus* (Duffy *et al*., 2009) and probably *P. knowlesi* (Cox-singh *et al*., 2008).

3.2.3. Nipah virus

Globally, the rate of tropical deforestation is highest in Asia (Mayaux *et al*., 2005). In 1997 and 1998 more than 10 million acres of virgin forest burned in Borneo and Sumatra, set ablaze by humans but exacerbated by a severe El Nino Southern Oscillation event drought. It's implicated that the effects of the El Nino Southern Oscillation (ENSO) phenomenon in 1997/98 posed to the emergence of *Nipah virus*. Malaysia had experienced a severe drought that directly preceding those outbreaks resulting from the El Nino conditions. The situation was aggravated by the excessive haze produced by the aggressive slash and burn deforestation activities in Indonesia. The haze and habitat loss are thought to have caused a mass exodus of "flying fox" fruit bats (*Pteropus*) searching for food, resulting in an unprecedented encroachment on cultivated fruit trees (Chua *et al*., 2002). This series of environmental and human events may have affected the natural habitat of the *pteropid* bats, forcing their migration and subsequent encroachment into fruit orchards surrounding the pig farming area, resulting in the unanticipated introduction of *Nipah virus* from its natural host to pigs as the amplifying host (Kok *et al*., 2009).

3.2.4. West Nile Virus

The transmission of *West Nile virus*, a zoonotic pathogen, can be directly linked to climate conditions. Birds act as reservoirs for the virus and mosquito vectors pass it from birds to humans. Temperature and humidity influence the distribution and density of many arthropod vectors and influence the incidence and northern range of vector-borne diseases as *West Nile virus* (Parkinson and Butler, 2005). Although birds, particularly crows and jays, infected with *West Nile virus* become ill or die, most infected birds survive and become reservoirs for the virus. The intensity of the virus fluctuates across the four seasons, peaking in summer and declining in fall and winter when the mosquitoes become dormant. Warmer, wetter summers will increase mosquito populations, while warmer winters will allow the virus to migrate (Barker and Lindsay, 2000). The introduction of *West Nile virus* into the United States in 1999 was a dramatic example, as was the introduction of *Usutu virus* to Europe from Africa in migrating birds (Weissenböck *et al*., 2002).

3.2.5. Avian Influenza virus H_5N_1

A good example of a pandemic zoonotic disease that could be impacted by climate change is avian influenza. Avian influenza viruses occur naturally in wild birds without producing any illnesses, however, a highly pathogenic strain of the disease named H_5N_1 is currently a major concern because it can affect humans and cause high case fatality. The first clinical respiratory illness of H_5N_1 avian influenza occurred in Hong Kong in 1997, when 18 human cases were reported during a poultry outbreak. It broke the species barrier to infect humans, cats, and tigers. So far it has affected many countries in Asia, Africa, and Europe. This emerging situation is mainly because severe winter conditions and droughts, occasioned by climate change can disrupt the normal migration pathways of wild birds and thereby bring both wild and domestic bird populations into greater contact at remaining water sources. So climate change influence the avian influenza virus transmission cycle and directly affect virus survival outside the host (Gilbert *et al*., 2008).

Climate change can alter bird migration patterns, changes in populations of waterfowl species, influence avian influenza virus transmission cycle. The European Union has already experienced during early 2006 that very cold weather in some areas causing feed scarcity and unusual freezing of open waters forced wild waterfowl to change their flyways which have led to the introduction of Highly Pathogenic Avian Influenza of the H5N1 subtype into the European Union (CEC, 2009).

3.2.6. Rift Valley Fever

Rift Valley fever where the virus is primarily a zoonotic disease, spread among vertebrate hosts by the mosquito species called *Aedes*. Primarily under flood conditions, *Culex* mosquitoes may feed upon infected ungulate hosts. This vector is referred to as a bridge species because it feeds on humans also, resulting in a spread of the virus outside its normal zoonotic cycle (Wilson, 2001). Rift Valley Fever (RVF), an important zoonotic viral disease of sheep and cattle, is transmitted by *Aedes* and *Culex* mosquitoes. Epizootics of RVF are associated with periods of heavy rainfall and flooding. In east Africa, with the combination of heavy rainfall following drought associated with ENSO (Little *et al*., 2001). ENSO related floods in 1998, following drought in 1997, lead to an epidemic of RVF and some other diseases outbreak in the Kenya/Somalia border area, causing the deaths of more than 2000 people and two-thirds of all small ruminant livestock (Anyamba *et al*., 2002).

3.2.7. Anthrax

Anthrax is an acute infectious zoonotic disease of most warm-blooded animals, including humans, with worldwide distribution. The causative bacterium, Bacillus anthracis, forms spores able to remain infective for 10-20 years in pasture. Temperature, relative humidity and soil moisture can affect the successful germination of anthrax spores, while heavy rainfall may stir up dormant spores. Outbreaks are often associated with alternating heavy rainfall and drought, and high temperatures (Parker *et al*., 2002). Changes in green-up and precipitation sporadicity in conjunction with rangeland expansion could indicate that some changes in the epidemiology of anthrax could occur such as longer anthrax seasons and an exposure of animals to more areas where B. anthracis may exist (Peterson *et al*., 1999). Because large anthrax epizootics often appear to occur after specific rain events in association with overall hot, dry summer conditions (Turner *et al*., 1999; Parkinson *et al*., 2003).

3.2.8. Leptospirosis

Leptospirosis remains one of the most common and most zoonotic infections worldwide (Levett, 2001). In India, leptospirosis is a major health problem obviously related both to the monsoons and poor sanitary conditions, with multiple epidemics reported in recent years (Sharma *et al*., 2006; Manocha *et al*., 2004; Karande *et al*., 2003). Thailand has been the source of a leptospirosis outbreak in the 21st century, subsequent to flooding, and localized mainly in the northeast region of the country (Tangkanakul *et al*., 2005). Fears of the emergence of leptospirosis outbreaks following the 2004 tsunami disaster was possibly due to the beneficial effect of salt water mixing with fresh waters (Ellis *et al*., 2005).

4. Impact Of Other Factors On Emerging And Re-Emerging Zoonoses

4.1. Microbial adaptation as internal factors

Microbes are a special component of adaptation and genetic change under selective pressure for survival and replication. The remarkable adaptation of microbes to become resistant to an antimicrobial product is seen in both humans and animals populations and is linked between the two (Gupta, 2001). Transmission of adaptive genetically changed microorganisms from animals to humans, either directly or indirectly through domestic animals, may occur in many ways (Bell *et al*., 2004).

Microbes, like all other living things, are constantly evolving (Soares, *et al*., 1993; Davies, 1994). Antibiotic resistance may emerge due to the selective pressure from antibiotic usage as seen in multi-drug resistant *Salmonella* species. Multi drug resistance *Yersinia pestis* has emerged in Madagascar (Chanteau *et al*., 1998). The emergence of antibiotic resistant bacteria as a result of the ubiquity of antimicrobials in the environment is an evolutionary lesson on microbial adaptation, as well as a demonstration of the power of natural selection. Selection for antibiotic resistant bacteria (Soares *et al*., 1993; Davies, 1994) and drug resistant parasites have become frequent, driven by the wide and sometimes inappropriate use of antimicrobial drugs in a variety of applications (Bloom and Murray, 1992).

Pathogens can also acquire new antibiotic resistance genes from other, often nonpathogenic, species in the environment (Davies, 1994). Zoonotic pathogens may acquire novel virulence traits that offer survival advantages. *Chikungunya* is an example of pathogen adaptation with the A336V mutation that is only found in strains from *Ades albopictus* mosquitoes contributing to the recent outbreaks (Gould and Higgs, 2009). Severe acute respiratory syndrome (SARS) is an example of likely microbial adaptation. It is caused by a SARS associated *coronavirus* and is believed to have emerged in Guangdong, China, in November 2002 (Guan *et al*., 2003).

Changes in natural conditions also often lead to a genetic evolution of microorganisms, such as genetic reassortment and recombination, horizontal transfer of virulence elements, and antimicrobial resistance, possibly resulting in the transition of microbes from nonpathogenic to pathogenic, from low virulence to high virulence, thus causing the emergence of zoonotic diseases. One example of the effects of genetic reassortment on the emergence and re-emergence of zoonotic diseases is Highly Pathogenic Avian Influenza (HPAI) H_5N_1 (Cardona *et al*., 2009).

Influenza A viruses possess a genome of segmented RNA fragments and genetic reassortment usually happens (Gutierrez *et al*., 2009). If a host is co-infected with two different subtypes of avian influenza virus, new viral particles will probably be assembled by genetic reassortment, in which some gene fragments come from one subtype and some come from another. This genetic reassortment contributes to newly emerging pathogens of humans and animals, such as the recent emergence of the swine origin influenza A (H_1N_1) virus (Lei and Shi, 2011).

4.2. External factors

4.2.1. Change in the ecosystem

Ecological change or disruption as a result of agricultural or economic development is one of the most frequently identified factors in the emergence of new zoonotic diseases. Agricultural or economic developments are especially the most frequent factors in outbreaks of previously unrecognized diseases with high case fatality rates, which often turn out to be zoonotic introductions. Ecological factors usually precipitate emergence by placing people in contact with a natural reservoir or host for an infection which is previously unknown but usually already present which achieved either by increasing proximity or, often, also by changing conditions so as to favor an increased population of the microbe or its natural host. Since humans encroach on new habitat, it is a certainty that they will be exposed to novel pathogens that could move from their four footed or avian niches into humans to cause disease (Daszak *et al*., 2000).

In addition to this, there is also the anthropogenic movement of pathogens into new geographical locations, a phenomenon that has been termed pathogen pollution, which results in an emergency of new zoonotic diseases (Daszak *et al*., 2000). Anthropogenic movement of uninfected hosts to new regions might also allow for diseases to emerge. An example here is the introduction of brushtail possums from Australia into New Zealand. In New Zealand, the possums have served as a very viable reservoir for bovine tuberculosis (Viggers *et al*., 1993). The emergence of Lyme disease in the United States and Europe was probably due largely to reforestation (Barbour and Fish, 1993).

Agricultural development, one of the most common ways in which people alter and interpose themselves into the environment, is often a factor of diseases emergency. For example, *Hantan virus,* the cause of Korean hemorrhagic fever, is a natural infection of the field mouse *Apodemus agrarius*. The rodent flourishes in rice fields; people usually contract the disease during the rice harvest from contact with infected rodents. Another example is *Junin virus,* the cause of Argentine hemorrhagic fever, which occurs as a result of Conversion of grassland to maize cultivation, favored a rodent that was the natural host for this virus, and human cases increased in proportion with the expansion of maize agriculture (Johnson, 1993).

Human population growth and over exploitation of the land, such as logging, mining, road construction, and agricultural production has resulted in deforestation. These changes, in turn, cause a cascade of factors that aggravate the emergence of zoonotic diseases, such as forest fragmentation, population migration, pathogen introduction, and environmental pollution (Patz *et al*., 2004). Deforestation forces wildlife to leave their habitat, increasing interactions among humans, wildlife, and livestock, and thus the potential for the transmission of pathogens directly or indirectly to human beings (Qing *et al*., 2007; Fu and Ma, 2008).

One of the key products of anthropogenic land use change is the fragmentation of wildlife habitat, which alters the composition of host species in an environment and the fundamental ecology of microorganisms. Top predators and other species at higher trophic levels usually exist at low population density and are sensitive to changes in food availability. The smaller patches left after fragmentation reduce sufficient prey populations, causing local extinction of predators and a subsequent increase in the density of their prey species (Ostfeld and Keesing, 2000).

In general, the loss of biodiversity due to deforestation and anthropogenic land use has an impact on the transmission of zoonotic diseases by the dilution effect. It is reasoned that in areas of high biodiversity, more species sustain vectors and the disease is diluted. If there are fewer species, the burden of disease is higher (Vora, 2008). Clear cut logging doesn't increase the zoonoses risk, but selective logging may do so as the forest biodiversity is maintained (Wolfe *et al*., 2005). Therefore, increasing diversity provides a dilution effect a buffer against disease risk that is lost when habitat is fragmented (Schmidt and Ostfeld, 2001).

4.2.2. Role of wildlife and animal migration

Many new zoonoses are viruses that emerge as human and domestic animal populations come into increasing contact with wildlife hosts of potentially zoonotic pathogens (Taylor *et al*., 2001). The risk for emergence of new zoonotic agents from wildlife depends largely on the diversity of wildlife microbes in a region (Morse, 1993), the effects of environmental change on the prevalence of pathogens in wild populations, and the frequency of human and domestic animal contact with wildlife reservoirs of potential zoonoses (Moya *et al*., 2004).

Opportunities for the emergence of zoonotic diseases depend on the frequency of contacts between wildlife species and humans. Some animals may be the known hosts for unknown pathogens that may cross the species barrier unexpectedly e.g. long tailed and pig tailed macaques are the known natural reservoir for *P. knowlesi* which has recently been found to be transmitted to humans by simio-anthropophagic *Anopheles cracens* mosquitoes (Vythilingam *et al*., 2008). Other known pathogens may have an as yet unknown animal source e.g. the discovery of SARS-like *coronaviruses* in bats as the likely natural reservoir for SARS-*CoV* (Wang *et al*., 2006).

RVF distribution is partly due to the migration of herds. Any changes to this as a result of deforestation or changed land use may lead to the introduction of RVF in new areas. Migration of wild birds is involved in WNF transmission. With alteration in seasons, changes in migration patterns and duration may be seen (Chevalier *et al*., 2004). Wild aquatic birds are the natural reservoir for Highly Pathogenic Avian Influenza (HPAI) and these migratory birds have been shown to excrete and act as long distance vectors for HPAI (Keawcharoen *et al*., 2008).

4.3. Socioeconomic factors

4.3.1. Agricultural practices and livestock farming

Agricultural practice leads to deforestation, which forces wildlife reservoirs of zoonotic diseases into closing proximity with humans. For example, the sudden emergence of *Nipah virus* disease in pigs and humans in Southeast Asia in the late 1990s may have been caused by rapid deforestation to clear land for farming timber production. The natural reservoir for *Nipah virus* appears to be fruit eating flying foes (bats in the genus *Pteropus*). As deforestation reduced their native food sources, flying fox population were thrust into closer contact with commercial fruit orchards and fruit trees on pig farms, where virus spread to pigs and then to humans (Chua *et al*., 2002).

Farming animals allow new pathogens to increase their numbers exponentially. This high intensity farming allows pathogens e.g. *E. coli* O157: H7 strains that may occur in small numbers to spread rapidly. Domestic animals themselves are reservoirs of zoonotic diseases. For example, the first cases of pig farming related Methicillin Resistant *Staphylococcus aureus* (MRSA) in the Netherlands (Voss *et al*., 2005). These porcine ST398 strains are nontypeable by conventional methods and are spreading throughout Europe. Farming is now considered a risk factor for Livestock-associated MRSA (LaMRSA) (Schlundt *et al*., 2004).

4.3.2. Human demographic, behavioral and cultural factors

Human behavior and demographic factors can influence zoonoses with wildlife reservoirs. The interaction of demographic trends in the latter parts of the 20th century and growth of population with animal and animal products causes the appearance of emerging and re-emerging zoonoses (Statical Divission, United Nations, 2003). Hiking, camping and hunting are activities that may represent the risk factors for acquiring certain zoonoses with wildlife reservoirs such as tick borne zoonoses and tularemia while eating meat from exotic animals such as bear increases the risk of acquiring trichinellosis (Schellenberg *et al*., 2003).

Researchers have identified several social and cultural factors as drivers of emerging zoonotic diseases (Patz *et al*., 2000; Daszak *et al*., 2001). Changing demographics and unprecedented population movement, as well as increased global flow of people, goods, food-animals, food products, and domestic and wild animals, all affect microbial traffic and emerging viral, bacterial, and parasitic zoonoses (Morse, 1993). Social changes resulting in altered land and water use patterns, intensified agricultural practices, deforestation and reforestation, and human and domestic animal encroachment on wildlife habitats also affect the movement of pathogens. These factors contribute to cross-species pathogen transmission and the emergence of new epidemic diseases that affect humans and animals, including the transmission of zoonotic diseases to humans and the anthropogenic movement of pathogens into new geographic spaces affecting the health of wildlife (Daszak *et al*., 2001). Massive urbanization has significant public health implications, increasing the occurrence of emerging and re-emerging zoonoses transmitted by water or air, as well as those diseases transmitted through animals or insects, due to the poor healthcare systems and inadequate infrastructure (Gong *et al*., 2012). Accumulated garbage provides food and habitats for rodents and other stray animals, and inadequate water supplies make it necessary to store water in containers, which will become an ideal habitat for mosquito larvae. These factors contribute to emerging and re-emerging zoonotic diseases related to arthropods and rodents, such as Japanese encephalitis, dengue fever, and epidemic hemorrhagic fever (Wu *et al*., 1999). Urbanization also promotes population movement and migration from rural areas to the urban environments this make people more vulnerable to infectious diseases due to financial constraints, overcrowded and unsanitary living conditions. In addition, to this their mobility promotes the transmission of infectious disease agents (Gong *et al*., 2012).

4.3.3. Lack of food safety

Food-borne pathogens are associated with the emergence and re-emergence of zoonotic diseases. In 2005, 1.8 million people worldwide died of diarrheal diseases due to contaminated food and drinking water (Newell *et al*., 2010). Although the burden of diseases caused by food-borne pathogens remains largely unknown in China, there have been many public health emergencies related to food borne pathogens during the past 20 years. For example, a large outbreak of human angiostrongyliasis occurred in Beijing in 2006, affecting 160 persons (Wang *et al*., 2010). From 2004 to 2009, 15 outbreaks of human trichinellosis occurred in China, resulting in 1387 cases and four deaths (Cui *et al*., 2011). Other important food borne zoonotic pathogens include *Salmonella* species, *Campylobacter* species, *E. coli*, and *hepatitis E virus* (Shao *et al*., 2011).

Food-borne zoonotic pathogens are increasing due to large scale food production, food processing, and distribution. Enterohaemorrhagic *E. coli* O157:

H7 outbreaks are associated with undercooked meat (Schlundt *et al*., 2004). Multi-drug resistant strains of *Salmonella* species (*Salmonella Typhimurium* DT104 and *Salmonella Newport*) are also emerging (Egorora *et al*., 2008). Many factors are associated with the emergence and re-emergence of food borne zoonotic diseases, including the global market in meat and farm animals, the habit of eating raw or undercooked food or wildlife, and the increasingly immunocompromised population (Newell *et al*., 2010).

4.3.4. International travel and commerce

The ever increasing world population and migration of masses in search of a job to urban areas, lead to overcrowding, inadequate sanitation, and hygiene, which provide an ideal breeding ground for infectious agents. Increased international travel, especially without taking the appropriate vaccine and other protective measures, lead to increased infection in travelers, who subsequently bring the infection back own homes on their return (Obi *et al*., 2010). Microbes are especially competent at adaptation and change under selective pressures for survival and replication. The remarkable adaptation of microbes to become resistant to antimicrobial products is seen in both human and animal populations and is linked between the two (Lonnie, 2004).

In addition to human movements, increased cross border trade of livestock and wildlife is also a concern. Trading centers, for example, can act as mixing bowls for humans and dozens of other species before they are shipped to other markets, sold locally, or even freed and sent back into the wild (Richard *et al*., 2011). The ease of transmission of emerging pathogens is facilitated by intercontinental travel. Efficient air and land travel links make disease containment difficult (Wilder-Smith, 2006).

The phenomenon of globalization has been one of the most remarkable changes in our lives over the last quarter of a century. Globalization has been the driving force that has profoundly impacted international trade, economics, and cultural interactions. The spatial mobility of the average human has increased more than 1,000 folds since 1800. At the turn of this century, almost 700 million people travelled internationally and this number is expected to reach 1 billion by 2010 (Eberharp, 2000). Not only more people travelling, but travel are faster and more culturally widespread and permeate into areas of the world not readily accessible in the past. People, animals, and products can circumvent the globe faster than the incubation period of almost every pathogen known today (Lonnie, 2004).

4.3.5. Bushmeat and hunting

One way in which wildlife serves as a source of infection is via bushmeat, or the use of wild animals for food, medicinal, traditional and cultural purposes, usually involving ingestion. Bushmeat is an important source of protein and income for millions of people, and the illegal bushmeat trade has been facilitated by the use of modern weapons and communication, logging operations that provide access to forests and transportation of products, lack of economic alternatives, and minimal capacity to enforce laws (Karesh and Noble, 2009). Bushmeat hunting, preparation, and consumption are linked with several pandemics and epidemics, most notably human immunodeficiency virus, and Ebola (Chapman *et al*., 2005; Daszak, 2006).

Hunting of nonhuman primates has historically been known to lead to the emergence of novel pathogens. The butchering of carcasses in forests, carry a high risk of transmission of airborne, droplet and contact spread zoonoses (Wolfe *et al*., 2005). Bushmeat may either be consumed as an inexpensive source of protein or as a sought after delicacy, according to the cultural value related to taste, wealth, and cultural significance. Bushmeat has cultural significance not only religious rites, which increase demand for meat (Adeola, 1992), but also ethnic identity, nostalgia, and social memory (Holtzman, 2006). Most bushmeat is not taken in a simple subsistence manner, that is, directly from the forest to the table. An estimated 90 percent of all bushmeat consumed moves through a distinct and well organized market chain, with numerous nodes along the supply chain where the meat changes hands multiple times in the animal's death and its presence on the dinner table (de Merode and Colishaw, 2006). Repeated transmission of viruses to humans, most of which do not result in human to human transmission, is termed viral chatter (Wolfe *et al*., 2005).

For example, simian foamy viruses are known to infect bushmeat hunters regularly, but to date; there has been no evidence of human to human transmission (Wolfe *et al*., 2004). More bushmeat means more viral chatter, which will increase the incidence of human infections, increase the number of pathogens that may infect humans, and increase the probability of eventual human to human transmission of one of these agents. As food insecurity increases, the bushmeat market becomes essential and more lucrative, creating more opportunities for transmission of pathogens to humans. The consumption of wild animal products is also driven by cultural dietetic practices related to health promotion and disease treatment, known as zootherapeutics. Animal products are deemed to have medicinal value, and when consumed, play an important role in ethnomedical systems to increase strength as well as enhance virility (Afolayan and Yakubu, 2009).

4.3.6. Pets

The popularity of companion animals is a cultural phenomenon subject to social and economic contingencies. These include animals kept for display as well as animals for which humans develop a special relationship that extends beyond the animals' value for work, substance, or sale. (Peeters *et al.,* 2002). Pastoralists in Africa and Hindus in India have special relationships with cattle that extend beyond their monetary or exchange value. Dogs and cats are the most popular companion animals and are at once associated with positive health benefits ranging from physical health to mental health. At the same time, pet ownership increases the chances of zoonotic infection from several different types of diseases such as salmonellosis, cryptosporidium, toxoplasmosis and rabies. The transnational trade in exotic animals from birds to non-traditional companion animals (e.g., prairie dogs that carry monkeypox in the United States) is growing and creating new challenges for both human and animal health professionals and demands their closer collaboration (Pickering *et al*., 2008).

Zoonotic transmission of diseases harbored by companion animals is relating to the close contact with their owners (CDC, 2009). The following are some of the zoonotic diseases that occur as a result of keeping animals as pets. Despite the risk of HPAI (H5N1), backyard chickens are allowed in the kitchen and treated as companion animals by some Indonesians the same way an American might care for a dog or cat. Fighting cocks are groomed and handled daily by their owners who express considerable affection for them. Primates are kept as pets in parts of the Cameroon where high rates of the *simian immunodeficiency virus* have been recorded (Peeters *et al.,* 2002).

Human salmonellosis is associated with keeping exotic reptile pets. Petting zoos are popular in urban areas and animal contact has lead to *E. coli* O157: H7 outbreaks (CDC, 2009). The recent emergence of zoonotic leishmaniasis in Europe is partly due to the domestic dog being the major reservoir host.

5. Public Health Impact Of Emerging And Re-Emerging Zoonoses

Zoonoses have important impacts on public health and livestock economies representing 61% of all infectious organisms known to be pathogenic to humans (Taylor *et al*., 2001). Zoonotic diseases can be emerging, re-emerging which cause significant human morbidity and mortality that affect poor and marginalized communities. These diseases are massively misdiagnosed and underreported but impose a dual burden on human and animals. They affect poor and marginalized people in developing countries, who live in close contact with animals, often in unsanitary conditions, where health services coverage is inadequate. These diseases tend to be overlooked by clinicians as well as policy makers and are hence under diagnosed and hence underreported (WHO, 2010).

Wildlife species can be considered reservoirs of pathogens with the potential to infect humans and livestock (FAO, 2011). There is an indication that infectious diseases will continue to have a significant impact on our health, and the emergence and re-emergence of pathogens will threaten the health and wellbeing of people and animals throughout the 21st century (AVMA, 2008). Tropical countries with climate and weather that favor emerging infections is economically under developed, overcrowded and especially susceptible (Fineberg and Wilson, 2010). Low latitude areas are characterized by high biological diversity, including a greater array and abundance of potential pathogens. These areas coincide with large and growing populations in developing countries (Guernier *et al*., 2004).

Zoonotic diseases can rapidly cause extensive human suffering and death. For example, Rift Valley fever (RVF), a mosquito borne disease, caused 89,000 cases and 150 to 250 deaths during the outbreak in Kenya of 1997-1998 (WHO, 1998). Diseases transmitted by food and water usually also affect large numbers of people. In 1993, in the United States of America (USA), hamburgers contaminated with *E. coli* O157: H7 were served in at least 93 restaurants belonging to a fast food chain, thereby placing large numbers of consumers at risk. Over 500 children and adults became ill and four children died (Anon, 1993).

6. Situation Under Ethiopian Condition

In developing countries, particularly Ethiopia has a great coverage of pastoral areas with inadequate veterinary and health infrastructures and facilities, a low number of health professionals and less supply of medical inputs, the zoonosis issue is very critical. The livelihood of the pastoral community of Ethiopia is mainly dependent on livestock production (Admasu, 2003). This condition made the pastoralists to have an intimate relationship with their animals and zoonotic infectious, transmissible between humans and animals, are closely associated with pastoralism (Zinsstag *et al*., 2006; Schelling *et al*., 2007). Proximity to animals, food consumption behavior, problems related to contamination of milk and meat, inadequate supply of treatment drugs, harsh environment (hot, dry and dusty zones), and socioeconomic and cultural practices are the main factors that expose the pastoralists to different zoonotic diseases (Zinsstag *et al*., 2006).

Human behavior and level of education are further factors that may influence health status (Defo, 1996). Migration may put nomadic pastoralists at periodical risk of infection, especially around water points (Rahmann, 1996). Since the animal and human interface is very intimate and common event in the pastoral areas of Ethiopia, it is very difficult to address the health of animals and humans separately but better if integrated (Schelling *et al*., 2007; Zinsstag and Tanner, 2008). There is a knowledge gap about zoonoses not only in the pastoralists but also in the human health professionals found in the pastoral areas of the country (Angesom, 2015a). Even though the animal health assistants had better awareness about zoonoses, they did not collaborate with human health professionals to create awareness to the community. Moreover, those medical professionals who have a limited awareness of zoonotic diseases have never been diagnosed such diseases due to lack of diagnostic and therapeutic facilities in the health centers (Angesom, 2015b).

In general, Ethiopia identified as a hotspot for zoonotic disease events. For example, the country ranked number one hotspot for leptospirosis, the fourth largest hotspot for *Q fever* and Trypanosomosis, and the tenth for tuberculosis. Ethiopia has the 4th highest burden caused by zoonosis (Grace *et al*., 2012). These data indicate an already existing burden of zoonotic disease in the country. The burden has the potential to be exacerbated by the effects of climate change (Lau *et al*., 2010). Although only a limited number of studies have examined the effects of climate change and zoonotic disease in Ethiopia, the existing conditions seem suitable for the occurrence of climate induced zoonotic disease. Ethiopia's large livestock population, in conjunction with predicted increases in both temperature and flooding and an established burden of diseases, suggests that climate change may greatly increase the incidences of leptospirosis in the country. For example, in Wonji hospitals almost half of all patients tested for leptospirosis were positive (Yimer *et al*., 2004).

7. Conclusion And Recommendations

Changes in human social behavior and customs will continue to provide opportunities for microbes to produce unexpected epidemics. Climate change plays a great role in the occurrence of emerging and re-emerging zoonotic disease especially for those vector borne diseases by influencing host defenses, vectors, pathogens, and habitats. Other factors such as microbial adaptation, change in the ecosystem, animal migration, and wildlife have a potential to cause such condition. The socioeconomic and political factors also result in emerging and re-emerging zoonotic disease. Even though the occurrence of a significant number of outbreaks of new and emerging zoonotic diseases over the past few years is a matter of concern, similar occurrences can be expected in the future as the continuous alteration of the environment and the establishment of human settlements in formerly uninhabited areas, particularly in the tropics. In general, all the above critical factors have been causing emerging and re-emerging zoonotic diseases in many ways over the past years and may continue causing in the future depending on the situation.

Therefore, based on these facts, the following recommendations are forwarded:

- ➢ There should be better standards and guidelines for the regulation of commerce, travel and bushmeat hunting.
- ➢ To mitigate the impact of climate change on the world and especially on Africa, studies on the epidemiology of zoonotic diseases are need to be done.
- ➢ There should be a widespread scientific agreement on the owing anthropogenic activities.

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