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Review on Ecology and Drivers of Emerging Infectious Disease

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Abstract: The objective of this review was to discuss the emerging infectious disease with respect to the effect of an altered ecosystem, anthropogenic factors related to different faces (host, vector, environment, pathogen and progress in science and technology and how to combat emerging infectious disease using trans disciplinary approach as a tool. Progressively close associations between human society and the natural environment are driving the emergence of novel pathogens, with devastating consequences for humans and animals alike. Disease ecology is the study of host-pathogen interaction within the context of their environment and, the emergence of disease often occur following a driver, some of this driver are limited to climate and weather, economic development, human wildlife interaction, destructive ecological changes due to economic development and land use. An altered ecosystem services can feed back to modify drivers. Amongst those environment change has an impact on disease transmission by affecting pathogen and vector ecology, population density, economic or social changes that lead to increase human contact with novel pathogen and this species negatively affect human health. In principle loss in biodiversity can affect transmission of infectious diseases by changing host or vector abundance and alter evolutionary dynamics of virulence and transmission pathways. Keeping the health of ecosystem functions could also prevent the spread of disease through biological control which is a triangle connection of an external agent or pathogen, a susceptible host and an environment. Indeed beyond academic and collaborative work with trans disciplinarily approaches to emerging infectious diseases have been highlighted focusing on a more proactive approach to surveillance, health assessment and monitoring of domestic and wildlife populations as well as health and disease interactions with anthropogenic change and the ecological footprint is crucial as prevention and controlling tools.

Key words: Ecology · Ecosystem · Emerge · Host · Pathogen · Zoonotic diseases

INTRODUCTION

The change in ecology that are biological impoverishment, habitat fragmentation, climate change, increasing toxification, the rapid global movement of people and other living organisms have worked synergistically to diminish ecosystem function [1]. The change in climate, habitats and biodiversity would have effect on abiotic and biotic components of ecological niches, while social and economic change can offer species translocation and dissemination [2, 3]. The external drivers increasingly facilitate biological invasions, a major threat to biodiversity and ecosystems globally [4]. The non-native species disease-causing microorganism, parasites and disease vectors (e.g. arthropod vector) which substantial threats to human, domestic animal and wildlife population. Invasions by pathogens are, in public and animal health terms, emerging infectious diseases (EIDs) such as human immunodeficiency virus (HIV) and severe acute respiratory syndrome (SARS) [5, 6].

Historically, the first emerging infectious diseases occurred with people moving across Pleistocene land bridges and later because of domestication of animals and living in close dense regions; and so with that came small pox, measles and influenza [7]. However, in the late 20th century the term emerging infectious diseases (EID) was widely used after human infectious disease outbreaks happened, e.g. Lyme disease, AIDS and antibiotic-resistant microbial infections. Then after an increase in publication and funds for surveillance lead to this term regularly presenting the new disease [7]. Human emerging diseases can be caused directly by invasive pathogens, pathogens transported by invasive vectors or reservoirs,

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or facilitated by invasive species not directly involved in the life cycle or transportation of the pathogen, but rather promoting the presence and abundance of its vectors and reservoirs [8]. Every infectious disease is an emerging infectious disease until it establishes itself as an endemic disease over a period of time [9].

Several recent reviews of invasive species and diseases focus on species interactions and ecosystem processes [10]. The ecological and societal impacts of invasive species and pathogens differ across gradients of climate and land use and in the presence of that infectious disease can emerge by two steps (i.e. (1) introduction of the agent into a new host population whether the pathogen originated in the environment, possibly in another species or pathogen exist different from human infection (2) founding and further dissemination within the new host population [11] Whatever its origin, the infection "emerges" when it reaches a new population [12]. Keeping a healthy ecology can also prevent and improve emerging infectious diseases and preventable loss of life. Therefore, this article reviewed the driver of emerging infectious disease, the effect of ecosystem on disease, anthropogenic factors of emerging infectious disease associated with the host, vector, environment, pathogen characteristics and the growing of effect advances in science and technology, which should be prevented through disciplinarily approach.

Drivers of Disease Emergence: Drivers of emerging infectious diseases are well-defined as the primary causal factor of emergence [13]. Driver determining emergence in domestic animals and wildlife are similar to the driver for EIDs in humans [14]. Changes in ecosystem services are almost always caused by multiple, interacting drivers that work over time and over the level of organization and that happen intermittently. A driver is any natural or human-induced factor that directly or indirectly causes a change in an ecosystem [15]. Change of anthropogenic nature is at the basis of all EIDs in humans, livestock and wildlife [16, 17] Human population growth and economic development have transformed into a growing need for land, water and energy. This created a global set of close drivers of disease emergence including deforestation and associated biodiversity loss, climate change, imbalances in agricultural and food supply systems, increases in travel, trade and traffic and persistence of poor health systems and protection practices [18].

Effects of Ecosystems on Disease: The effect of the ecosystem on disease turns around the dilution and amplification of disease transmission caused in biodiversity change [19]. The converse how diseases influence ecosystems and their functioning clearly faces a more difficult challenge in measuring ecosystem responses [19]. The health of ecosystem directly affects human health [20] serves as a powerful reason for ecological restoration [21]. The human being is an influencer of ecological service. Considerable work remains, however, before human health is fully regarded as an ecological service in which anthropogenic land use change is the major driver of zoonotic pathogen spillover from wildlife to humans directly and through domestic animals to humans indirectly [22]. Identifying the lack of measurable linkage between the environment and human health as a principle causes a knowledge gap that limits understanding of ecology restoration as a public health service [23].

Destruction of the integrity of the ecosystem can take many factors, including deforestation, fragmentation, logging and draining or flooding of natural habitats. Such change expose to a human being too unfamiliar with lethal micro-organism [24]. Ecosystem degradation also has complex effect response and distinguishes negative impact on human health, including the prevalence of endemic/epidemic disease, vector and water-borne disease; air quality; nutrition; mental health; and access to traditional medicines; as well as effects on human health over the impacts of climate change. The change in ecology can alter the flow and reliability of the supply of ecosystem services that people receive from nature. These changes can, in turn, increase the vulnerability of people and ecosystems to further changes [25].

Emerging Infectious Disease: Emerging infectious diseases was commonly defined as, outbreaks of previously unknown diseases, known diseases that are rapidly increasing in incidence or geographic range in the last 2 decades and Persistence of infectious diseases that cannot be controlled (e.g. HIV infections, SARS, influenza viruses, Lyme disease, Escherichia coli O157:H7 (*E. coli*), hanta virus, dengue fever, West Nile virus and the Zika virus. The death of infectious disease by mode of transmission include: person to person 65%, food/water/soil 22%, insect/vector 13%, directly from animal <1% [26]. Any infectious disease emerges in human population due to the effect of something that has changed in the ecological balance. Indeed, these factors deal, directly or indirectly, with changes in the relationships of humans, animals and potential microbial pathogens [13]. The driver of disease emergence modulates the interaction between pathogen-host and environment [27]. The situation of emerging infectious disease can be considered as a shift in the pathogen-host-environment interaction characteristics which further create novel pathogens [28].

This process finally in a novel steady state pathogen–host–environment interplay [29]. The factor are increase in prevalence and suggest infections will continue to emerge and probably increase and emphasizes the urgent need for effective surveillance and control [30]. The CDC guide line to combat emerging microbe threats to the health; conducting laboratory based surveillance, good communication network (exchange of information about incipient trends in infectious diseases, analysis of factors contributing to disease emergence), improving of public health infrastructure was the cornerstones of prevention measurement strategy [31].

Anthropogenic Drivers of Emerging Infectious Diseases: Studies show that recently emerging infectious diseases caused by anthropogenic factors including change in land use (e.g. deforestation, mining, oil extraction, etc.), food production changes and global trade travel and lead the causes of disease emergence [32]. Much of these underlying drivers also overlap with the leading drivers of biodiversity loss and ecosystem disruption [33]. These practices are causing fundamental changes in the environment and facilitating increased human-animal contact.

Humans induce emerging infectious diseases to create a novel species and this leads to the evolution of the pathogen and host in response. Frequently the novel association of host and pathogen are the direct result of human activities; specifically global travel and trade connection with species ever before [34]. Humans also indirectly alter host, parasite and vector association [35].

The increasing temperature at higher altitudes and elevation allow parasites and their vectors to expand their range into communities where hosts are naïve [36]. Anthropogenic changes in land use help novel species association, allowing the parasite to infect a novel host. The association of parasites with agriculture and animal husbandry can spill over to wild species as well as humans [37]. The domestic host serves as a "stepping stone" for the parasite which can move from wild to domestic species [38]. Regularly these stepping stones act ecologically (increasing parasite population sizes and/or transmission opportunities), letting the parasite move into new species without evolutionary change. However, the genetic mutation will arise in the parasite that will allow it to successfully spill over into a novel host [39].

Host and Vector Characteristics: Human activities has association with urbanization and agriculture and it has major impact on species abundance [39]. Impact on host and vector density has an important role on ecology and evolutionary dynamics affecting parasite prevalence. When the host population becomes extremely dense the probability of parasite transmission increase and it also contributes to higher infection of prevalence than the epidemic state potentially increases [40]. Development of land increases the density of host species which contributed to epidemics; like for West Nile virus which is associated with urban and agricultural land use in North America [41], which result in elevated host density (bird) and vector (mosquito) in these habitats [42]. The virulence of parasite often correlate with transmission ability, as the parasite invite more host resource production more transmission stage and also more virulent [43].

Conceptually, when the parasite virulence and transmission rate are low, an increase in the likelihood of infecting additional hosts (i.e increase in parasite fitness), however, at a high level of virulence earlier host death may limit transmission [44]. Extremely virulent parasites can become a major threat to susceptible wild host species when spillover occurs [45]. Disease dynamics and possible host co (evolution) are affected by host density and the impact of species diversity on humans. Changing competing host density and/or probability of transmission, high biodiversity may decrease (dilute) or increase (amplify) parasitism [46]. Growing evidence suggests that anthropogenic reduction in biodiversity generally increases disease and such biodiversity-driven change in disease incidence may alter selection for host resistance that higher host diversity often correlate with higher parasite diversity [47].

Environmental Characteristics: The environmental change affects the population level of the host, vector and environmental stage of the pathogen and also its transmission rate which pathogen move between host, vector and environment and this change can affect disease burden which directly influence transmission but if the environmental change affects nutrition this can affect disease severity [48]. The contact rate quantifies the interaction between hosts or between a host and environment and is generally determined by host behavior and properties of the environment. Infectivity, or probability of infection given contact, is a function of both the virulence of the pathogen and the immune status of the host [49].

Environmental characteristic on infectious disease has three interlocking components: environment, transmission and disease. They defined change as social, such as urbanization and those that are ecologic, such as deforestation, but in actuality, any process affecting human health has both social and ecologic components that are intimately linked [50]. Environmental characteristics consist of population/demographic factors such as density, virulence and immune status, as well as those factors that influence the rate of transmission from one host to another, such as ingestion rate, vector biting rate and human-to-human contact rates. Understanding how environment changes address disease emergence and its transmission is critical for public health pandemic.

Pathogen Characteristics: There are many factors involved in the emergence of new infectious diseases, among these factors evolution of pathogens over time many are a result of human behavior and practices [51]. With regard to the pathogen characteristics of emerging diseases at least two events can happen just to say that (1), the infectious agent is introduced into a vulnerable population and (2), the agent has the ability to spread from person to person and cause disease [51, 52, 53]. An important factor influencing both the likelihood and outcome of disease emergence is pathogen invasion, i.e., the ability of a pathogen to emerge. The invasion is determined by the combination of pathogen traits, including opportunism and evolvability [54, 55]. Particularly, RNA viruses with an inherent high mutational rate, bacteria capable of acquiring genetic material and pathogens infecting multiple hosts are more likely to turn into an emerging disease agent [56, 57].

Many emerging diseases arise once infectious agents are passed to humans and the human population expands in number and is introduced into the new geographic area, there is a possibility of contact of human beings with animal species that are a potential host of an infectious agent increases. Human density and mobility combined with the introduction of new species, poses a serious threat to human health [58]. Climate change is a concern for the emergence of infectious diseases, as the earth's climate warms the habitat is altered and the disease spread into new geographic areas. Indeed The characteristic features of the emerged pathogen are mode of transmission, mechanism of replication, its pathogenesis or the means by which it causes disease and the response it provokes [52].

Progress in Science and Technology: Infectious disease emergence is associated with population density, travel, trade, land use change, environmental change and interaction between humans and wildlife [13, 18 and 59]. Using progressive technological reduced or simplified efforts of disease monitoring and disease modeling is important for the dynamics and epidemic prediction that is a better understanding of human mobility patterns have enabled situation of the spread of the novel pathogen and disease [60]. Modeling has the potential to assess and identifies hotspot of EIDs, where the pathogen emerge is more likely to occur [59]. Novel emerging infectious need new technologies such as rapid molecular identification, Web-based surveillance tools and epidemic intelligence used to facilitate risk assessment and timely outbreak detection [61].

Disease and Environmental Change: Environmental changes such as the loss of forests and the spread of cities are promoting conditions for a rise in new and previously suppressed infectious diseases and also it has influences disease burden such change resulting in unprecedented levels of disease emergence [62]. Anthropogenic changes (such as dams, canals, irrigation systems and reservoirs), cause populations to move and settle this can provide a chance to observe the relationship between environmental change and disease transmission [63]. The environmental changes are unevenly distributed across a region, thereby producing the conditions of a natural experiment, these relationships can be observed easily and systematically. For example, the impact of road construction on disease is associated with an increase in malaria [64, 65]. These increases in incidence were attributed to the presence of water pools created by road construction practices. In a recent study in the Peruvian Amazon, a mosquito biting rates are significantly higher in areas that have experienced deforestation and development associated with road development [66] and a study conducted in India situated in a higher prevalence of dengue vectors along major highways [67].

Biodiversity Buffers the Spillover of Emerging Disease: Biodiversity loss can affect the transmission of infectious diseases [68], by changing host or vector abundance [69], a greater diversity of host species can sometimes increase pathogen transmission by increasing the abundance of vectors [70], by changing the behavior of the host, vector, or parasite and by changing host or vector condition [68, 71]. In principle, higher diversity could influence behaviors with a resulting increase in disease transmission or could alter the evolutionary dynamics of virulence and transmission pathways [68]. The death of one species or the rise of one species at the expense of another may establish a cascade of ecological responses, fulvescens (reservoir for Choclo virus) and Zygodontomys brevicauda (reservoir for Calabazo virus), could be influenced by species richness, evenness, diversity and interspecific interactions within their community, particularly where fragmented landscapes are dominant [72, 73].

Trans-disciplinary approaches can be defined as integrating knowledge across and beyond academic disciplines in order to improve the prevention and control of emerging infections [74, 75]. Such an approach is the networking of professionals from the human, animal and environmental sectors to encourage global health by improving understanding of infectious disease spillover from an infected host and implementing strategies for preventing and controlling emerging disease threats [76].

Transdisciplinarity-collaboration support global health improvements, including surveillance science, diagnostic technologies, understanding of pathogen evolution and ecological driver identification. In addition, no one perspective, discipline, or world view constitutes a privileged place from which to understand the world or these intractable problems [77] respecting this assertion, transdisciplinarity “is about dialogue and engagement across ideologies, scientific, religious, economic, political and philosophical lines”. The collaborative work and transdisciplinarity approaches to diseases of wildlife and domestic animals have been highlighted as part of the growing discipline of preventive medicine, focusing on a more proactive approach to surveillance, health assessment and monitoring of wildlife populations as well as health and disease interactions with anthropogenic change and the ecological way [78].

This approach will ultimately allow for predictive models and a prompt regional and global response to infectious disease spread. A proactive/predictive approach to future outbreaks and the development of an agenda for environmental management of zoonotic emerging infectious diseases are necessary [79]. Strategies for a better understanding of wildlife–domestic animal–human disease interactions include (1) fostering collaboration among disciplines; (2) funding surveillance for emerging diseases in human animal and wildlife; and (3) identifying species that may serve as sentinels of ecosystem health. Sentinel species can be selected for their ability to reflect environmental agitations [80]. Based on their life history and physiological attributes, selected species can provide insightful information about environmental changes at various spatial, temporal and trophic scales [81].

CONCLUSION

Emerging and re-emerging infectious diseases are a key concern of global environmental problems with important public health, economic and political worry. The causative agent of most emerging infectious diseases was to be zoonotic. Anthropogenic and environmental change that affects the ecology/ecosystem and biodiversity is increasingly associated with disease emergence and spread. In the past year even in the last two and three years we have been faced with so many emerging and re-emerging infectious diseases, while its outbreak highlights the control in our understanding of the complexities of infectious disease. The reason for emerging and re-emerging infectious diseases was to be multiple and complex. The major factor that is given to emerging infectious disease is ecological change, an anthropogenic factor leading to change in biodiversity associated with the evolution and adaptation of pathogens and the transmission pathway. Regardless of the deriving factor, using mitigation measures by applying the transdisciplinarity approach beyond academic view and increasing advanced research methods associated with disease modeling and conducting web based surveillance were reducing the incidence and transmission of emerging infectious diseases. Indeed, or else the current global situation favors disease emergence and we may be faced with more outbreaks or pandemics of EIDs in the future.

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