Alternative ecological and social proposals for preventing the global threat of emerging infectious diseases.

Camille Besombes *

Independent researcher in the epidemiology of emerging infectious diseases, Paris, France.

* **Corresponding Author:** Camille Besombes, **e-mail:** camelia.bes15@gmail.com

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Abstract

Emerging infectious diseases are a major global health threat in the human, animal and plant worlds. Zoonoses and vector borne diseases are becoming prevalent worldwide. A large part of global health funding is dedicated to the fight against Dengue, Zika and Ebola diseases. Until now, public health strategies have been mainly based on vaccine development, medication testing or on proposals for "acceptable" cultural changes in local population practices to limit transmission risk, without thinking about the root causes. In this literature review, it will be argued that the current economic system, through its growth imperatives which ignore planetary limits, together with intensive agricultural practices, is related to infectious disease emergence. Monocultural practices, such as rubber/palm oil industrial plantations, through the ecological perturbation inflicted, act as a driver of vector borne and zoonotic diseases. Deforestation, loss of biodiversity, and human invasion of remote forested areas are followed by the emergence of zoonoses such as Ebola disease. Even if any emergence is always a multifactorial process, it is still fundamental to highlight the major influence of environmental drivers. The characteristics of specific ecological and social contexts within which emergence occurs should be explored. Alternative health and environmental paradigms could help impede the emergence of infectious diseases. A true "One health" approach which takes care of ecosystems and preserves the diversity of living things and of relationships corresponds to an "EcoHealth" approach. Ecological options and environmental solutions could produce a real innovation in public health. Stopping deforestation and ecosystem destruction and fostering peasant agroecology and *free evolution* for certain forested areas could slowly lead to rebalanced ecosystems. Furthermore, ecological actions would be less stigmatizing than promotion of cultural changes. An alternative public health program based on "health within a healthy environment" would be more effective than a secondary struggle against emerging diseases. This suggests introducing public health as a fundamental land use issue, inaugurating peasant agroecology, land use and conservation as fundamental public health issues, and developing coherent policies.

Key words: EcoHealth; ecological alternatives; ecosystemic approach to public health; emerging infectious diseases; pathogenic environment; Planetary Health; plantacionocene.

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2. Introduction

Since the 1960s, and particularly in the last 20 years, the emergence of infectious diseases has become a major source of concern on a global level (Jones et al., 2008). Emerging or re-emerging infectious diseases are defined as infectious diseases that have recently emerged in a population, or that existed previously but have increased in incidence or expanded their geographic distribution (Lederberg et al., 2003; Jones et al., 2008). There are two different types of infectious diseases: zoonoses, diseases transmitted from animals to humans as a result of cross-species spillover transmission, and vector-borne diseases, transmitted via a vector (mosquitoes, ticks) (Jones et al., 2008). Ebola disease and COVID 19 are current emerging zoonoses, while zika and dengue epidemics are recent examples of vector-borne diseases. Nearly 60% of human pathogens and about 60% of emerging infectious diseases are classified as zoonotic (Jones et al., 2008; Woolhouse & Gowtage-Sequeria et al., 2005). Satcher and Lederberg list "at least 29 diseases that have emerged in the last 28 years, most of which are zoonoses" (Satcher et al., 1995; Harper & Armelago., 2010). The number of both emerging infectious diseases and epidemic events has multiplied by 10 since 1940 (Jones et al., 2008).

In a world of major ecological and societal deterioration, these emerging diseases represent a global threat not only to human health but also to the health of the plant and animal worlds (Keesing et al., 2010). We cannot observe the ecological and societal changes in the anthropocene era without looking at the current globalized economic system and the dominant growth imperative along with a globalized intensive agro-industrial system. The changes in land use induced by the generalization of intensive agro-industry in order to increase world food production are held responsible collectively for 25% of infectious diseases and half of zoonoses (Keesing et al., 2010; Rohr et al., 2019; Karesh et al., 2012; IPBES, 2020).

During the modern era of public health policy, the attention paid to the natural environment has fluctuated as a result of biomedical thinking with a reductionist trajectory (Porter, 1999). In the 19th century, health campaigns based on acting on the causal chain of diseases focused on hygiene and the quality of housing and accommodation. The 20th century, however, saw the evolution toward a technological and biomedical turning point. A return to the root causes of diseases and environmental determinants has been taking shape in recent decades, particularly in terms of the epidemiology of infectious diseases (Eisenberg et al., 2007).

Biomedical approaches to understanding the causality between environmental determinants and infectious diseases need to be redefined. In fact, the clinical categories used by the medical diagnostic approach do not correspond with the categories used in ecology, with reference to environmental determinants. Indeed, the medical approach based on groupings by symptoms, by affected organs or by pathophysiological functioning is incompatible with the major categories of ecological effects. The use of both categories - zoonoses and vector-borne diseases, defined on the basis of modes and cycles of transmission - is already more relevant in attempting to analyze the environmental determinants of emerging infectious diseases (Wilson, 2001; Eisenberg et al., 2007). Similarly, the risk factor approach used until now is somewhat outdated in terms of the complexity of root causes, and in its ability to examine causal mechanisms at multiple scales (Pimentel et al., 1998; Eisenberg et al., 2007). The processes that affect human health have both a social and an ecological component, which are inextricably linked (Eisenberg et al., 2007; IPBES, 2020). To include social and environmental determinants and their impacts over the course of a person's life requires specific tools. A more appropriate approach in establishing causal networks would be to take into account these different components, their interactions and feedback loops.

A growing share of global public health spending is devoted to emerging infectious diseases, especially this year with the recent COVID 19 pandemic. To date, in the context of Global Health, global public health responses to infectious diseases have tended to focus on the biomedical and therapeutic aspects through drug development or vaccine research (IPBES, 2020). Prevention is mostly secondary prevention, usually focused on suggestions for acceptable cultural changes or the promotion of new social norms (Biehl & Petryna, 2013). The fundamental thesis of Global Health is based on the triad: technical solution, individual compliance and cultural barriers (Biehl & Petryna, 2013). In emerging and developing countries, the multiplication of vertical silo approaches, paying attention to a single disease, remains the rule (David et al., 2020). Horizontal and holistic approaches to strengthening the public health system as a whole are not favoured

(David et al., 2020). Furthermore, “colonial legacies shape the geopolitics of Global Health and work their way into programme and research design, implementation and monitoring” (LSHTM, 2020, p.1; Anderson, 2014). Such a paradigm needs to be questioned: both as regards the objectives of this colonial medicine, aimed at maintaining a population in good physical and reproductive health in order to ensure its economic productivity (Pépin, 2020) and also in light of the results obtained by these medical practices (Pépin, 2020; Lachenal, 2014; Anderson, 2014).

It is now established that the ecological, societal and human imbalances inherent in the functioning of our global economic system contribute to an increase in the probability of infectious disease emergence (Daily et al., 1996; Morse et al., 1995; Morand & Walther, 2020; Crutzen et al., 2002; IPBES, 2020), and many authors have begun to explain the links between large-scale ecological imbalances and these emergences. However, there has been very little research done on the fight against the root causes of these emergences and the preventive responses to be considered in order to curb these processes.

In this literature review, we will try, firstly, to shed light on the impact on public health of the growth-based global economic system by focusing on the consequences of the intensive agro-industrial system, through some practical cases and general considerations concerning zoonoses and vector-borne diseases. Secondly, having focused on the root causes of emergences will enable us to examine what public health responses could look like in terms of ecological, social and ecosystemic alternatives in the fight against emerging infectious diseases.

2. Emerging Infectious Diseases as Health Consequences of an Intensive Economic/Agro-industrial Model

The growth-based global economic system, particularly through the spread of intensive agriculture and monocultures, the extraction of fossil fuels and the globalization of transport, has well-known global consequences such as pollution, climate change, the destruction of ecosystems and ecofragmentation (Morand, 2020; Crutzen et al., 2002). However, the impacts of this system on public health related to emerging infectious diseases have been less directly highlighted.

This globalized functioning based on economic growth objectives, without taking into account planetary limits, has led to the ecological and social state of the world now known as the Anthropocene. Thus, we will use the term Anthropocene to discuss the consequences and different aspects of this growth-based system, even if the term *capitalocène* could be more relevant to describe what makes the current system pathogenic (Crutzen et al., 2002; Bonneuil & Fressoz, 2013). While the term Anthropocene is highly controversial, the environmental signatures of this epoch have profoundly affected the state of global public health (Mac Michael et al., 2014; Whitmee et al., 2015; Zywert,2017; Zywert & Quiley, 2020). Deforestation has increased at an unfaltering rate since the 1950s: five million hectares were deforested each year between 2001 and 2015, mainly in Brazil and Southeast Asia. The reason for this deforestation is the strong demand for soybeans for livestock and palm oil for industrial food and biofuels. Oil palm plantations currently cover more than 27 million hectares of the Earth's surface. Humans are destroying natural environments at an accelerated rate: 100 million hectares of tropical forest were cut down between 1980 and 2000 and more than 85% of wetlands have been removed since the beginning of the industrial era. These Anthropogenic processes have resulted in the emergence of a multifaceted degraded environment, ultimately resulting in the creation of pathogenic ecosystems. Indeed, the inherent demands of this economic system, and in particular intensive agricultural practices, have changed the world to the point of causing the emergence of ecological and social environments conducive to the development and establishment of various pathogens and infectious diseases. In this way, environments in reshaped areas (ecotones) and periods of major restructuring over time (chronotones) appear to have played a determining role in the genesis of emerging infectious diseases (Bradley et al., 2004). Pavlovski established the connection between a disease and a defined geographical landscape (Pavlovski, 1964). In the same way that we use the term Anthropocene, we could also use the term *pathonocene* to allude to a period characterized by specific diseases resulting from anthropocenic changes, such as emerging infectious diseases (Méthot, 2016; O'Callaghan-Gordo & Anto, 2020).

As suggested by Donna Haraway (2016) and Malcolm Ferdinand (2019), the term *Plantacionocene*, might be an even more appropriate and accurate way to describe both recent history and the present-day, stemming from a global change in land use and human resources. "The use of the term 'plantationocene' connects the development of a plantation form of production to the beginning of the current geological era that we are in" (Hameed, 2017, p.2). "[We use the term] Plantationocene for the devastating transformation of diverse kinds of human-tended farms, pastures, and forests into extractive and enclosed plantations, relying on slave labor and other forms of exploited, alienated, and usually spatially transported labor…" (Haraway 2016, p.162) "Plantations eradicate the diversity of what is cultivated, devastating the land, and expropriating the bodies working on the land and destroying any possible autonomy for self-sustenance for those living in these areas" (Hameed, 2017, p.2). The *plantacionocene* is characterized by a homogeneization of living beings and their interconnectivity. This way of inhabiting the world cannot be understood independently of capitalism. Moreover, the anthropogenic processes at the origin of today's environmental devastation are intertwined with a colonial and slave-oriented way of thinking (Ferdinand, 2019). The intensive agro-industrial system based on the generalization of monoculture and plantations, irrigation and the use of fertilizers, has had a profound impact on rural lifestyles. Concerns about the health impacts on communities has been raised, from the occupationally exposed farm worker, to the inhabitants of agricultural areas that are subject to multiple routes of exposure. Moreover, these modified ecosystems and the non-resilient communities resulting from such changes are now having increasing difficulty coping with the numerous disturbances incurred. On a global scale, these modified environments correspond to *hotspots* of emergence: since the 1960s, South Asia has been the site of a large number of emergences (Dengue virus, Kyasanur forest disease, Nipah virus, Cov2 SARS, etc.) (Karesh et al., 2012; Bradley, 2004). Moreover, the concentration of humans in big cities, the centralization of the food production system (Rohr et al., 2019), together with the failures of public health systems following international austerity policies (Lachenal, 2013) have led to a very vulnerable world (Satcher, 1995; IPBES, 2020).

The focus of this paper is on these deep roots of emergences and I will not discuss other diseases which are also characteristic of the Anthropocene such as certain respiratory and cardiovascular diseases, obesity or certain neoplasias, nor the impact of current food production patterns on nutritional status. It is, nevertheless, important to note that chronic non-communicable diseases may contribute to the occurrence of severe forms of infectious disease, as seen in the current COVID 19 pandemic (Cicolella, 2020). This recalls the concept of pathocenosis, which emphasizes the interdependence between different diseases. A community of diseases emerging in an ecological and social context specific to a particular period of history is also influenced by the interrelationships with other diseases of that time (Grmek, 1969; Whitmee et al., 2015; Mac Michael., 2014; Gonzalez et al., 2010).

Vector borne diseases

Recent decades have witnessed the expansion of vector-borne diseases with, in particular, the epidemic of Zika in South America in 2015, the worldwide spread of Dengue fever and its severe forms of haemorrhagic fever, and the spread of Lyme disease in Western countries (Lowe et al., 2018; Stanaway et al., 2016 ; Li et al., 2019). Several factors come into play in the geographical distribution of vector-borne diseases, including land use changes, anthropization and urbanization of areas, climatic factors, and socioeconomic inequalities.

The relatively rapid transformations characterizing this period are called *chronotones*, whereby rapid change brings together risks inherent in the current, previous and following periods (Bradley, 2004). The epidemiological importance of chronotones should be emphasized. For example, changes in land use through the expansion of monoculture and industrial plantations lead to major disturbances at each stage of the transformation, whether during the initial phase of deforestation or during the phase of planting a single/clonal plant species over a large area, or during the exploitation phase (Bradley, 2004). These modified environments cause functional changes in local biodiversity and changes in the distribution and balance between different species. (O'Callaghan-Gordo & Anto, 2020; IPBES, 2020). The resulting altered environments are often unfavourable for many wild species but can become favourable for generalist species that develop the capacity to adapt to these anthropized environments. For example, the installation of permanently irrigated rice fields or oil palm plantations provide favorable conditions for the development of mosquito larvae and are followed by malaria epidemics (Kuriakose & Ittyachen, 2018). The model of permanent irrigation of rice fields is a relatively new phenomenon resulting from the demands of ever-increasing productivity and yields caused by a system of international trade. Similarly, the expansion of palm oil plantations has taken place in the context of the globalization of trade and the generalization of processed food. Another example is the use of chemical fertilizers that promote the proliferation of *Aedes aegypti* and *Anopheles gambiae* (malaria vector) (Darriet, 2018). The generalization of the use of chemical fertilizers is also a byproduct of the demands of growth within the agricultural model. Furthermore, monocultures appear more susceptible and less resilient to crop pests that can lead to food insecurity. The existence of plantations also changes the relationship between humans and their environment, increasing human exposure and the interfaces between different species. Indeed, this system leads to movements of susceptible populations of workers to plantations and increases their exposure within environments that have become ideal habitats for vectors. Thus, rubber workers must go to the plantations each morning to harvest the sap, at a time that is most favourable for the bites of malaria-transmitting mosquitoes. In Thailand's Chachoengsao province, 60% of malaria cases were identified among rubber plantation workers. (Ecohealth Asia, 2011) The exploitation of rubber to supply various industries, especially the tyre industry, illustrates one aspect of the growth imperative. The world expansion of rubber exploitation took place first during the colonial period and then during the Second World War, two periods that correspond to important moments in the emergence of the current economic system. Exposure to zoonotic malaria based on human use of space in Borneo, Malaysia has been studied. At the community level, data indicate that areas near secondary forests and houses have the highest probability of human exposure to *P. knowlesi* (zoonotic malaria), providing quantitative evidence of the importance of these border zones between heavily reworked and wilder areas called *ecotones* (Forgnace et al., 2019). Finally, the rural exodus and urbanization, together with the proliferation of informal and precarious housings and a lack of waste and wastewater management, have favoured vector-borne diseases, such as Dengue fever and Zika (cluster of microencephalies following Zika infections among pregnant women in the favelas in Brazil) (Paupy et al., 2009; Ali et al., 2017).

Dengue fever poses a health threat to two fifths of the world population, with an annual incidence of around 80 million cases, 500,000 severe haemorrhagic forms and 300,000 related deaths (Halstead, 1999). The incidence of Dengue fever in the world has increased more than 30 times over the past 50 years. In Southeast Asia, and particularly in Malaysia, the re-emergence of Dengue occurred in the early 1950s at a time of significant and early land use changes, with the expansion of oil palm and rubber tree plantations, and associated deforestation and urbanization (Toha et al, 2014). It has been argued that the transformations of forest ecosystems into industrial plantations have had an impact on the epidemiology of Dengue (Brown et al., 2018). During the 1950s, vector-borne disease management based on environmental vector control measures was successful and led to the eradication of some vectors such as *Aedes aegypti* (vector of Dengue, Zika, Yellow Fever and Chikungunya) from several South American countries (Paupy et al., 2009). After the development of a Yellow Fever vaccine, vector control efforts and more broadly environmental and ecological vector control measures were abandoned, leaving room for the reintroduction of the vector in the 1980s (Paupy et al., 2009). Since then, the density of immunologically susceptible human population, human migration, and uncontrolled urbanization have led to the proliferation of vector and epidemics (Paupy et al., 2009). Poor housing seems to be the cause of the amplification of epidemic and human mobility a determinant of the spreading of pathogens.

Other anthropogenic processes influencing vector-borne diseases, including disturbances of aquatic environments caused by mining or the creation of irrigation channels, have an impact on diseases transmitted via freshwater crustaceans, such as Buruli ulcer or bilharziasis. Buruli ulcer is caused by a bacterium and manifests itself in the form of decaying skin ulcers, while bilharziasis is caused by a parasite and leads to urinary tract obstructions and neoplasia. The recent expansion of illegal and legal mining in French Guiana has caused epidemics of Buruli ulcer in areas previously free of the disease (Jagadesh et al., 2019; Combe et al., 2019; Douine et al., 2017). The increase in industrial and small-scale mining extraction puts pressure on ecosystems and causes major public health problems among the indigenous populations of the exploited areas (direct effects: water pollution, intoxications; and indirect effects: alcoholism, prostitution, insecurity). In the same way, the construction of major historical canals has resulted in the spread of malaria and bilharziasis around the world and particularly in Egypt (Guerra et al., 2012).

Other environmental factors such as climatic disturbances have already brought about changes in the geographical distribution of different vectors, notably *Aedes aegypti/albopictus* (vector of Dengue, Zika and Chikungunya) leading to new clusters of Dengue and Zika in previously unaffected areas (Lowe et al., 2018; Stanaway et al., 2016). In Western countries, the expansion of the distribution of *Ixodes ricinus* ticks (vector of Lyme disease) is leading to an increase in the incidence of Lyme disease cases (Lin et al., 2019). Indeed, climate seems to be a major determinant of the geographical and seasonal distribution of arthropods and mosquitoes (Karesh et al., 2012), which operate as ecological drivers of vector ecology.

Finally, socioeconomic inequalities must also be highlighted as determinants of vector-borne diseases: the estimated incidence of Dengue fever is 32% among the population on the Mexican side of the US-Mexico border while it is 4% on the Texan side. That can be caused by differences of living standards, quality of waste management, wastewater, access to drinking water and access to a quality health system (Ramos et al., 2005).

Zoonoses

Zoonoses and epizootics result from the exchange of pathogens between species. Cross-species transmission by spillover occurs in humans both through domestic animals and wild fauna. The Neolithic agrarian revolution, characterized by the advent of animal domestication and the settlement of human populations, corresponds to the first period of emergence and establishment of several zoonoses such as measles and tuberculosis (Morand, 2020; Harper & Armelago2010). More recently, the industrialization of animal husbandry in the 1960s with the establishment of high animal concentration farms paved the way for the development of zoonoses such as H1N1 influenza (Keck & Lynteris2020; Karesh et al., 2012). The encroachment of livestock farms on wildlife habitats ever closer to forests is increasing the interfaces between wildlife and livestock. The weakening of the genetic diversity of domestic animals through genetic selection increases the genetic susceptibility to a pathogen that may have been benign in wild populations (Morand, 2020). Finally, the industrialization of the world and the globalization of the meat/food market have played a crucial role in these emergence processes, allowing the rapid spread of these diseases around the world among susceptible populations (Morand, 2020).

Tropical regions are the areas of greatest and most rapid ecological change, in which “only remnant patches of undisturbed forest in a sea of cropland persist” (Haddad et al., 2015, p.1; Wilcox & Gubler, 2005; IPBES, 2020). Deforestation has resulted over time in the fragmentation of about 60% of the subtropics and 45% of the tropics (Haddad et al., 2015). Timber extraction, road construction in remote areas and eco-fragmentation of wildlife habitats all have direct ecological impacts on wildlife (IPBES, 2020). The increase in poaching that results from the easy access to the forest, and the growing demand for bushmeat in the cities contribute to the loss of biodiversity and the increase of zoonotic risk (Guégan et al., 2020; Morand 2020; IPBES, 2020). These ecological degradations, directly linked to a mode of land use, favour the interspecies transmission of zoonotic viruses, through the increase in interface and contact zones. The conversion of natural spaces into agricultural or urban areas, the simplification of habitat and the reduction of species diversity all lead to the proliferation of potential reservoirs (Morand, 2020; IPBES, 2020). These altered environments, or anthropogenic ecotones, seem to be particularly implicated in the processes of infectious disease emergence (Despommier et al., 2006). The connection between ecotonal processes and ecological and evolutionary biophysical processes is arousing interest in studying these specific areas (Despommier et al., 2006). For example, Ebola epidemics preferentially occur in recently deforested areas (Oliveiro et al., 2017). In these areas, the expansion of oil palms acts by "truncating ecosystemic barriers that interrupt chains of transmission and driving a coevolutionary socioviral system across a critical point" (Wallace, 2016, p.3).

Potential changes in these areas in the local abundance of certain susceptible species, or the introduction/proliferation of invasive species may cause ecosystem imbalances and induce human-assisted pathogen diffusion (IPBES, 2020). The scarcity of native species, the collapse of fauna and the disappearance of predators lead to the disruption of ecological communities and the hyperabundance of invasive species such as rodents (Wilcox & Gubler, 2005). Invasive rodent species are indeed recognized as reservoir hosts for many zoonoses: lassa virus, leptospirosis, monkeypox virus, etc. (Meerburg et al., 2009). Changes in land use seem to have a particular impact on the proliferation of rodents. On the one hand, plantations or rice fields appear to be favourable for rodent feeding and, on the other, the disappearance of predators has led to the colonization of these anthropized areas (Singleton et al., 1999). Bats have also been identified as a reservoir of many pathogens: the Ebola virus, the Marburg virus, the Nipah virus, the SARS Cov virus, etc (Bordes et al., 2015). The displacement of bat populations through the destruction of their habitat, the increase in the areas of exchange between bats, livestock and humans are also implicated in these multiple emergences (Morand, 2020).

However, the problem is not only that of the species carrying the pathogens, but the impoverishment of ecosystems that reduces the dilution effects of opportunities for transmission to humans (Keesing et al., 2006; Everard et al., 2020; Civitello et al., 2015). “In a rich ecosystem, a pathogen is more likely to encounter so-called ‘poorly competent’ hosts, i.e., unfavorable to its multiplication, or even ‘dead-end’ species” (Keesing et al., 2006, p. 489; Everard et al., 2020). On the contrary, the less rich the ecosystem, the more likely it is that a pathogen will eventually pass into humans. The impoverishment of ecosystems therefore considerably increases the risk of transmission to humans (Keesing et al., 2006; Everard et al., 2020). Even more than the loss of biodiversity, the loss of functions promotes the transmission of pathogens and its persistence (Wilcox & Gubler, 2005; IPBES, 2020). Certain points of no return, or tipping points, induce irremediable imbalances after being exceeded. Wilcox & Gubler (2005) introduce the concept of *pathogenicity thresholds*: "existence of threshold of pathogen persistence to explain much of the increase in emerging infectious diseases". As described by Plowright et al (2017), "Zoonosis emergence corresponds to the rare alignment of gap in barrier". The alteration of complementarity between species may affect the regulatory functions of bi-directionality and thus influence infection dynamics (Cunningham et al., 2017). Disease containment could therefore now be considered an ecosystem service. Indeed, preserving ecosystem services is recommended, at least as regulators of disease (Cunningham et al., 2017; IPBES, 2020), and above all in themselves for their intrinsic value.

The third epidemiological transition?

The first epidemiological transition occurred with the Neolithic revolution, human settlement and the beginning of agriculture, which resulted in a specific pattern of infectious and nutritional diseases. The second epidemiological transition is characterized by a decline in infectious diseases and an increase in chronic/degenerative diseases. This appeared during the last two centuries following the establishment of an intensive agricultural system. If an epidemiological transition is defined by a break in the causes of mortality, does this shift in threats related to emerging and re-emerging infectious diseases, such as zoonoses, vector-borne diseases or antibiotic resistance, generate enough evidence to speak of a new epidemiological transition (Harper & Armelago, 2010)? Do these emerging pathogenic environments, accompanied by diffusion capacities never before equaled in global transport, lead to what would correspond to a third epidemiological transition? Could the health impacts of the generalization of pathogenic environments characterize our era? If so, emerging infectious diseases and anthropocene-induced pathogenicity make up the third epidemiological transition. In this case, the agro-industrial system and especially the use of land for plantation would be at the origin of the third epidemiological transition, providing the basis for the term *plantacionocene.* The recent international crisis linked to the COVID 19 pandemic is further confirmation of this transition. Indeed, if emergences always correspond to multifactorial processes, it is fundamental to highlight the major influence of environmental determinants in recent emergences and the current health crisis. Ecological and social ecosystems are characterized by dynamic equilibriums, and the disruption of these beyond certain thresholds has led to major disruptions threatening human life on a global scale. Global causes generate long-term systemic effects. These emergences reveal an extreme fragility through the homogeneity and the major interconnections of our life styles, leading to a systemic impasse composed of system-based issues and to long- and short-term harmful pathways.

General effects of the growth-base economic system on the current health care system

Driven by the global growth-based economic system, today's healthcare system promotes a technomedical vision of health, based on reactive medical and curative approaches (IPBES, 2020), on technoscientific solutions mainly defined by Western countries and on preparation policies for potential health or security crises (Lachenal, 2013). These approaches have long been questioned both for their ineffectiveness and for their difficult acceptability. The Western biomedical approach to health and disease, through the medicalization of lives, has come to exceed deleterious thresholds and to generate multiple iatrogenies (Illich, 1976; Zywert,2017). Health policies defined according to the current economic model sometimes result in counterproductive measures and can worsen the health situation. The control methods developed in response to certain zoonoses transmitted by rodents can lead to significant health consequences. For instance, compensating for the disappearance of predators through the use of chemical pesticides has important limitations in terms of effectiveness but also in terms of human and environmental health (Jacquot, 2013). The destruction of all rats during human plague epidemics has the paradoxical consequence of increasing the human epidemic, with fleas seeking new hosts after the rodents have died (Plowright et al., 2017). Some methods also induce counterproductive effects: "inadequate or inappropriate policies of vector control promoted vector or disease emergence", for example, the selection pressure on mosquitoes through the generalization of pesticide use has selected resistant mosquitoes (Wilcox & Gubler, 2005). Moreover, in the past, failure to consider the ecological and ecosystem roots and contexts of health problems has led to counterproductive measures. Reaching counterproductive thresholds could be summarized as follows: "Exploitation of the environment has contributed to human health. By exploiting Earth resources we have a more comfortable existence, and our life spans have increased considerably. But we're now at a tipping point in which the exploitation of the environment is beginning to have a negative impact on human health” (Seltenrich et al., 2018 p. 1; Aillon & D'Alisa, 2020). Finally, top-down and authoritarian public health interventions, such as the promotion of acceptable cultural change or quarantines are not very well accepted by populations, regardless of geographic location. They sometimes lead to the rejection of proposals by the communities concerned and to stigmatization. Indeed, in the recent Ebola epidemic in North Kivu, community mistrust resulted in the lynching of health workers involved in the public health response (Changle, 2019). While current vertical programs may appear to be ineffective or even counterproductive, community-led and controlled interventions are likely to be more appropriate (Sturmberg & Njoroge, 2017).

In addition, there are inconveniences inherent in the medico-technical health system and new biotechnological innovations: the techno-scientific world co-produces problems and needs, hopes and promises. It pursues the utopia of eradicating infectious diseases initially carried out by colonial medicine, particularly in sub-Saharan Africa, with the same disproportion and the same potentially deleterious effects and failures (Anderson, 2014). In fact, efforts to eradicate African trypanosomiasis, also called sleeping sickness, in French Equatorial Africa, through forest management, agricultural development of the area, and the isolation of diseased populations in specific villages, paradoxically led to an increase in the incidence of sleeping sickness during the colonial period. In addition, the massive campaigns of treatment for eradication using non-sterile material led to secondary contamination and the spread of other infectious diseases (Pépin, 2020; Lachenal, 2014). Moreover, the promotion of technoscientific solutions is currently being updated, for example, in the fight against vector-borne diseases with genetically modified mosquitoes by genetic forcing. Malaria in sub-Saharan Africa or Dengue fever in South America are the object of these highly technological battles. Firstly, the health benefits are not ensured, while the uncertainties linked to biotechnologies and the risks of off-target effects induce "unknown unknowns" (Boëte et al., 2002). Field experiments in southern countries of techniques incompletely developed by northern countries, without proven epidemiological effectiveness in terms of the current state of knowledge, appear ethically questionable (Boëte & Koella, 2002; Meghani & Boëte, 2018). Moreover, these techno-scientific solutions are promoted through philanthropic funding, as in the case of genetically modified mosquitoes promoted by the Bill and Melinda Gates Foundation (MacGoey, 2015). Finally, the specialization and expertise of public health responses, which cannot be appropriated by populations, leads to South-North dependence and a loss of autonomy in health matters. Yet, in the history of public health interventions, the most effective strategies to reduce the burden of infectious diseases have been found to be hygiene and improved living conditions, where vaccination or antibiotic therapy have played only a secondary role quantitatively. Basic interventions and health prerequisites thus appeared to be more effective at the population level than the latest technological innovations (Armstrong et al., 1999; Szreter, 1988). Moreover, success obtained with antivirals or antibiotics is always temporary, notably due to inherent antimicrobial resistance, although basic interventions are more durable.

The concept of preparedness now dominates in Global Health institutions, referring to a programme of long-term development activities whose goals are to strengthen the overall capacity and capability of a country to manage efficiently all types of emergency and to bring about an orderly transition from relief through recovery and back to sustainable development. This concept of preparedness has replaced the concept of prevention and the precautionary principle, and so has heralded a new era in public health. This concept of preparedness for specific and anticipated risks has erased other previous modes of operation that favoured the resilience and basic functioning of health systems, allowing for the unexpected. Paradoxically, these systems have never appeared less prepared to respond, less effective in times of crisis, than since when the concept of preparedness has been dominant.

At the same time, with the emergence of Global Health, funding for public health has shifted from state and public funding to philanthropic and charitable funding (MacGoey, 2015; Packard, 2016), while the guarantee of fairness and justice is borne by taxation according to income and on the equitable participation of all in the financing of public services. European countries, which until now have been more backward with respect to these practices, have recently reinforced this model, notably to deal with the COVID 19 crisis (calls for donations to provide medical equipment to hospitals have multiplied). With the emergence of Global Health in the 2000s, public health became a market like any other, defined by financial investments and health products (MacGoey, 2015; Packard, 2016). This new approach is also characterized by two types of health interventions: security interventions against emerging threats/biosecurity and humanitarian interventions (Lachenal, 2013). This represents a major change in the concept of international health developed after 1945 (Packard, 2016). Finally, the infiltration of the economic context into the public health system has induced reactive and short-termist choices, while the temporal dimension of ecosystem balances would require protective interventions in the long term (Everard et al., 2020). Faced with an epidemic, the development of a treatment is the preferred type of intervention: rapid intervention, focusing only on the consequences, centered on the symptoms of the imbalances at the origin of the emergences and not on the imbalances themselves. Conversely, identifying the pathogenic relationships and determinants of the ecosystem involved, and then attempting to restore the ecosystem functions and balances at stake in the epidemic, are long and demanding processes that attempt to act on the upstream causes of emerging infectious diseases. Like the globalization of the economic system, the consequences in terms of public health are found worldwide, as are the causes. The large-scale commodification of nature and the industrialization of the world have similar consequences on all continents, even though the countries of the South are by now decades ahead in terms of ecological and social/societal degradation.

Finally, a by no means negligible effect of the economic system is the chronic destruction of public health systems and of the health capacities of countries, through the economic adjustment policies conducted by the Global Fund (David et al., 2020; Lachenal, 2013). These restrictions result firstly in major failures of health systems, and subsequently in economic and social conditions conducive to epidemics and their severe societal consequences. The role played by economic adjustments in the spread and severity of the 2014 Ebola epidemic in West Africa has been already described (Lachenal, 2014b).

The health crisis linked to COVID 19 sheds light on this phenomenon, this time in Western countries (Soener et al., 2020). In fact, the policies of financial restrictions and layoffs in public hospitals have led to a breathless and ill-equiped hospital system (both in terms of material and human resources) at the start of the epidemic, with all the difficulties that we have become familiar with. The European countries that have been most affected by the disengagement of the state and by the budget cuts in public health financing in recent years are also the countries that have appeared to be the most vulnerable and most affected by the health crisis, such as Spain and Italy (Soener,2020). Economic austerity policies are leading to humanitarian crises, this time in developed countries: "Years of austerity have left us ill-prepared for the coronavirus and exposed how vulnerable we are" (Soener,2020, p.8). The coexistence of public and private systems in the health sector has led to inequalities in access to care and a loss of state control over the health care provided (MacGoey, 2015). Not surprisingly, India, a country characterized by a 60% privately based health system, found itself without care capacity during the COVID 19 epidemic, with the private sector initially refusing to treat COVID patients (Nair, 2020). Furthermore, vaccines and new drugs induce fears and reluctance among populations, fears that could probably be avoided if research and development around curative approaches were entirely public, ensuring a non-profit approach.

Ecological vulnerability, epidemiological vulnerability, health system vulnerability, social vulnerabilities: these multiple incurred vulnerabilities characterize the Anthropocene. Such systemic and interconnected vulnerabilities can thus lead to cascading effects and the aggravation of health crises (Machabala & Karesh, 2015). Understanding the ecological changes that play the role of drivers of pathogen emergence and spread is essential for effective and targeted measures against emerging infectious diseases.

3. EcoHealth: ecosystemic approaches and ecological and social alternatives.

Alternative approaches to health

The results on the health consequences of a system that creates the conditions for the occurrence of diseases and their potential spread are the same as those described by Aillon et. al., who argue that "the current model of development is not compatible with the protection and promotion of health of present and future generations" (Aillon & Dal Santo 2014, p. 1; Aillon & D'Alisa, 2020). In this respect, the global expansion of pathogenic environments appears as the result of the artificialization of wild environments themselves, linked to an extractivist and productivist system and a land use based on industrial plantation. Dealing with the complex public health problems resulting from the combination of Western lifestyle and capitalist socio-economic structure calls for a break with the dominant paradigm, to move beyond it to an alternative framework. Could alternative approaches to health be able to influence these human-made health problems?

Alternative approaches to public health could mean thinking about health holistically. Thinking about health in historical and evolutionary terms, taking a step back far enough to understand the emergences, dynamics and pathocenoses (combinations of diseases characteristic of an era and the interrelationships between them). Long-term studies of the impacts of anthropogenic modifications on environments are necessary, as a short-term scale does not allow for the identification of imbalances inherent in any modification of ecosystems (IPBES, 2020). The understanding of health leads to an interest in the health of the environment at all scales: from the health of the external environment (health of the ecological and social environment) to the health of the internal environment (microbiota). Our ecological external environment influences directly our microbiota, reminding us that we are part of a single living environment (Leroij et al., 2020). If thinking upstream of health is based on encouraging health promotion through a healthy environment, thinking downstream of health is also important: in particular to avoid environmental degradation which ensues from many action which aim at the production of health itself (medical waste management / contribution of disposable medical material to environmental pollution/ testing drugs on animals) (Lavocat, 2020). It is important not to reinforce, on the grounds of an exceptional situation, the factors that have led us directly to the current impasse. Thinking about emergences in terms of causal networks, complex causality, complex interactions with adapted approaches would make possible to better define the determinants of health. Approaching health in an alternative way would also call for considering decolonial health, which means questioning current and past public health networks, and fostering the autonomy and independence of action of populations for their own health. Conceptually, this way of thinking has the aim of producing cross-fertilization with humanism, decolonialism, collective management of the common, eco-feminism, etc. The question to be asked would therefore be: which human health should be favoured so as to promote the health of environments and other living beings as a prerequisite for promoting human health in return?

This would correspond to health promotion and *primary* prevention, rather than *secondary* prevention or preparedness, based on fighting diseases once they have emerged. Such alternative approaches to public health would promote an alternative use of land that pays attention to the sustainability of our planet, its limits, and to the health of ecosystems and non-human beings *for a more-than-human public health* (Kehr, 2020). Environmental health calls for action on the environment to reduce the risk of disease emergence, focusing on the ecological and social conditions of life prior to the onset of disease. Understanding the origins of the viruses implicated must also complement this holistic approach, focusing on their animal reservoirs and potential hosts, their ecological habitats and the reasons for their sudden emergence at a particular time and place, when some of these viruses are known to circulate in that area at a level undetectable for a long period of time. Once again, public health policies focused on the prevention of the ecological and social determinants of emerging infectious diseases, in particular, on the prevention of imbalances and on the repair of ecosystems, are necessary.

Peasant agroecology could be one approach (Les notes de sud, 2020). This is a set of agricultural practices that rely on the functionalities offered by ecosystems, aiming at reducing the impact of agriculture on biodiversity and natural resources, coupled with a social movement in defense of sustainable and equitable agricultural and food systems respectful of humans. Such approaches emphasize the traditional knowledge of local communities, preserving local specificities and habits, while being nourished by the most recent global knowledge. Environmental and social justice and the respect of human rights are an important part of this agroecology, together with solidarity. Small-scale animal husbandry, with a reasonable animal density, a high genetic diversity and a farming method that respects living beings could help limit the impact of pathogens on livestock and humans. Agriculture preserving landscape mosaics, diversification and large forests, developing active hospitality practices for biodiversity, would all have a positive impact on ecosystems. The aim would be to reintroduce agriculture in its place within ecosystems, agriculture as a link between ecosystems and humans. Instead of being a driver of epidemics, agriculture could in this way assume a regulatory role. Halting the extraction of fossil resources should also be encouraged not only to avoid the deterioration of ecosystems and the physical health of riverine populations, but also to preserve the social health of communities by stopping the deterioration of human relations. More broadly, alternative approaches to health would also involve a deglobalization of trade and a reduction in global transport, which would contribute to reducing the risk of transmission and spread of pathogens but would also imply a more global transformation of our societies so as to make it acceptable. These restrictions on travel should not be equated with restrictions on freedom, since they will not be so when accompanied by other transformations of lifestyles within territories and ecosystems.

Changing our relationship with our environment involves changing the way we relate both to humans and non-humans. The concept of cooperation could be explored in the way proposed by Kropotkine in the same period during which the dominant paradigm was the competition between living beings as defined by Darwin. Kropotkine's ecological observations in the hostile and harsh environment of Russia, at the same time as Darwin was conducting his observations in the abundant environment of the equatorial zone, led the two men to different conclusions. In difficult environments, cooperation and mutualism appear to be fundamental for survival (Kropotkine, 1902).

The “One Health” concept

Different ideas of an integrated approach to health have been developed in recent decades, such as the "One Health" concept that considers health at the human-animal-environment interface (Roger et al., 2016; IPBES, 2020). While the “One Health” concept is indeed a step forward in terms of a holistic approach, it is now widely accepted within traditional institutions and remains mainly focused on the health of domestic animals within the agro-industrial system, while wildlife or ecosystems are under-represented (Roger et al., 2016). Such an approach cannot be integrated into a truly alternative approach. In this model, the fight against threats related to zoonotic infections focuses on improving the health and productivity of animal husbandry and food safety and security, without questioning the functioning of the system and the root causes of the health problems encountered (Mi et al., 2016). Moreover, this approach, despite its desire to integrate, still maintains the traditional separation between domestic and wild, and is based on the danger that animals represent. A truly “One Health” approach should favour “living with”, “living together” with ecosystems and non-humans and take into consideration ecological, environmental and ecosystemic solutions in order to be a real breakthrough in public health.

The “EcoHealth” concept

Another concept, that of “EcoHealth”, has been developed in the same period. For the moment, it has remained essentially at the stage of local experimentation, while it has the potential to correspond to concrete applications of the principles of sustainability in health (Morand & Walther, 2020; Morand et al., 2020) and constitute such a breakthrough. In contrast to “One Health”, “EcoHealth” is a socio-ecosystem approach to health, more focused on environmental and socio-ecosystemic problems (Nguyen Viet et al., 2015; IPBES, 2020). The foundations of “EcoHealth” are based on disciplines such as ecology, ecosystem health, population health, and the focus is on optimizing ecosystem health in order to improve human health (Mi et al., 2016). "[The] ecosystem approach to health formally connects ideas of environmental and social determinants of health with those of ecology and system thinking" and diseases appeared as "Public health issues, individual and population expressions of interacting systems" (Wilcox et al., 2012, p.4). “EcoHealth” is based on the inextricable links between the health of all species and the health of their environment, taking into account social, ecological, population and ecosystem health, the intrinsic values of an ecological system, and the participation of indigenous societies and knowledge (Lerner & Berg, 2017). It is a method based on community ecology, population ecology, landscape ecology and system ecology, with the aim of determine a "disease landscape": a more coherent vision of the local determinants of diseases and of the local imbalances leading to emergences. The ultimate goal is to highlight the potentially most effective interventions in terms of prevention and to seek to understand and mitigate the factors of the physical and social environment affecting health (Mi et al., 2016). This paradigm shift allows us to move from a linear, thematically-segmented approach to a systemic and multidisciplinary approach more adapted to the complex systems under study.

More recently, within the context of the Anthropocene and the awareness of planetary limits, the concept of "Planetary Health" has also emerged, accompanied by the slogan “our planet, our health” (Myers et al., 2018; Morand & Walther, 2020; Morand et al., 2020). This highlights unexpected health outcomes of climate change and human influence on the Earth and focuses on characterizing the health impacts of anthropogenic alterations in the structure and function of Earth’s natural systems. It responds to a pressing need for new directions for environmental health: “If you’re building a highway through the Amazon, you need to methodically look at what that means for vector-borne disease. And today, we don’t do that. We have to look at the pros and cons of these actions in terms of economic impact, social impact, environmental impact, and public health impact” (Seltenrich, 2018, p.6). However, in the “Planetary Health” approach, the ecosystem is considered as the biosphere and the external environment and not as the lived environment of living beings.

Both “EcoHealth” and “Planetary Health” could be summarized as proactive health promotion rather than surveillance and preparedness in term of public health policies (Mi et al., 2016; WHO, 1986). Such approaches could be the precursor of a radical transformative switch from reactive behaviour toward proactive preventing pandemics (IPBES, 2020). Thus, “EcoHealth” and “Planetary Health” could have benefits to develop mutually in collaboration, both in terms of a theoretical view and practical applications.

Practical applications of the “EcoHealth” concept: ecosystemic approaches and ecological and social alternatives

What is necessary for us is to try to act on the root causes of emerging infectious diseases and on the health problems defined by the communities themselves, rather than just managing the health consequences of ecological imbalances. From this perspective, a better understanding of each determinant specific to the emergence studied would make it possible to subsequently decide on the level of intervention specifically adapted to the disease and especially to its ecological context, and not simply to suggest the use of a solution independently of the context. These suggestions favour both more targeted measures, specifically adapted to the local context, and more radical public health policies with a broader global scope.

Methods

The methods developed by the "EcoHealth" approach begin with an ecological/ecosystemic diagnosis: an assessment of the specific health situation and the area concerned by a recent emergence, conducted on the basis of indicators of animal health, human health and ecosystem health. The ecodiagnosis of the bio-social-ecological zone enables us to determine its pathogenic potential, in order to try to avoid the emergence of the disease or its spread by acting on the management of the eco-social environment. This starts with the definition of the health problem of a community by itself, followed by understanding the complex causalities, the virtuous and vicious cycles at stake and the possible consequences of different interventions, through the exploration of multiple perspectives. Finally, it results in several choices. Which relationships should be the focus of the intervention? How, where and when should we intervene in a system to better address critical relationships? What underlying mechanisms are at the origin of these emergences in this community at a given moment in human and environmental history? What recent short- or long-term ecological changes have occurred in this area and can explain the imbalances that have emerged? Several tools are useful for this practice, such as village resource maps or village weakness maps that help identify critical points (Nguyen-Viet et al., 2015).

This first stage of analysis is then followed by environmental management adapted to natural resources to promote a healthy ecosystem and "filling the gap between disease and health" (Roger et al., p.2; Nguyen-Viet et al., 2015). It consists of the search for "practical solutions that reduce or reverse the negative health effects of ecosystem change and which can bring about improvements to human, animal and ecosystem health" (Nguyen-Viet et al., 2015, p.5). Finally, it corresponds to strategies to reduce and reverse the risks on the environmental aspect. "EcoHealth" based on field experiences seeks to understand how agricultural practices can contribute to improve health (Nguyen-Viet et al., 2015), how to develop more sustainable agricultural practices by integrating the avoidance of eco-fragmentation or the establishment of ecological corridors for wildlife movement. Indeed, ecohealth is an approach focused on the territories and populations concerned and emphasizes the essential role of ecobiosocial strategies focused on the community.

Examples

Public health responses to vector-borne diseases, after a shift from chemical to biological control, could now move towards environmental management/source reduction with community involvement. This approach would correspond to changes in agricultural practices, based on vector ecology, notably through the identification and management of larval breeding areas. The seasonal increase in vector-borne diseases such as Dengue fever and malaria is a major concern in rice paddies in tropical parts of the world. A health ecology experiment is taking place in Mwea Kenya (SIMA System Wide Initiative on Malaria and Agriculture) (Mutero et al., 2005). It is based on agricultural alternatives to rice cultivation, through the cultivation of soybeans 6 months a year, in parallel with the use of insect repellent plants around the home. This experiment has resulted in the reduction of malaria cases along with a better nutritional status for the populations (Mutero et al., 2005). Practical examples of the Ecohealth approach could also correspond to the fight against vector-borne diseases by favouring the predators of the vectors: bats, insectivorous birds, amphibians, dragonflies (ID4D, 2020).

The "Building out Vector" program is another example of the implementation of environmental planning for health purposes. This program proposes fighting against the socio-sanitary determinants of health problems and in particular vector-borne diseases by improving human housing and accommodation in order to eject the vectors. Waste management programs and the improvement of sanitary conditions in informal urban settlements, leading to the destruction of larval breeding areas, can reduce the incidence of vector-borne diseases such as Dengue fever (BOVA network, 2020). Another illustration of this approach took place in a Mexican city with multiple health concerns (Dengue fever epidemic, intestinal diseases, and polychlorinated biphenyl pollution). An environmental health promotion intervention involving all levels of civil society and government resulted in a decrease in the risk of Dengue fever according to different entomological indices (Breteau index: from 50 to 13.3%, household index: from 40 to 6.7%, container index: from 4.6 to 1.1%) in a pre- and post-intervention evaluation (Alamo-Hernandez et al., 2019).

The meta-analytic work carried out by Keiser et al (2005) is rare. Through the study of various malaria control methods built around environmental management, she examined the impact of these interventions on reported clinical cases of malaria around the world, on the basis of different eco-epidemiological parameters. In 16 studies involving environmental modification (permanent) or environmental manipulation (temporary), the risk ratio was reduced by 88%. (Keiser et al, 2005). In mathematical models based on the modification of human habitats, the malaria risk ratio was reduced by 79% (Keiser et al., 2005). This type of evaluation and inter-community comparison between different interventions in different countries is essential in order to assess the effectiveness of interventions based on environmental modification such as health ecology. However, in order to achieve a truly significant impact on disease incidence, both large-scale and long-term interventions are a prerequisite (Alamo-Hernandez et al., 2019). The involvement of multiple partners such as the community and state institutions is the cornerstone of the success of these interventions.

Alternative methods based on ecosystem-based management have also been tested for several years in the United States against another vector-borne disease, Lyme disease. Management measures based on the choice of plant species in the gardens (Cosson,2017), on the management of tick predators such as birds (D'Estries et al., 2017), livestock (van Wieren, 2016a and 2016b; Hassan et al., 1991), and wild animals (Hofmeister et al., 2017a, 2017b) presented interesting results in terms of the reduction of risk.

Emerging rodent-borne diseases are also a major public health concern. Refocusing control strategies towards rodent management, rather than rodent control (traditional methods based on culling and eradication), could be more efficient, and requires promoting research in rodent ecology and ecosystem approaches (Singleton et al., 2004). Ecological Based Rodent Management research (EBRM) based on the biology and ecology of rodents considered as pests has enabled the implementation of management strategies that are more sustainable and less harmful to the environment than previous methods (Singleton et al., 2004). The importance of ecological, taxonomic and behavioural studies is to be emphasized in order to develop effective strategies. Specific environmental studies can help to determine the best way to be effective and what role could be played by the strengthening or reintroduction of predators, such as foxes (Singleton et al., 1999). Only a rigorous observation of territories and the species interacting in them over a long period of time can allow the definition of targeted and efficient control methods.

Metapopulation approaches and spatial population dynamics in farming systems have also been tested. Furthermore, knowledge of population dynamics and factors limiting rodent population growth has been used effectively in the management of rodents in palm oil plantations (Singleton et al., 1999). Rodent ethology-type training can also be used to limit animal resistance behaviour to control measures. Research needs to be conducted on the real impact on disease transmission of rodent abundance, of host community structure, of host density, of spillover mechanisms and of transmission chains (Bordes et al., 2015). All this while encouraging the involvement of local communities and farmers, who are the most familiar with their territories and have precious observation time at their disposal, reinforcing the relevant role of a peasant agroecology. The same approach could be used concerning bat-transmitted pathogens, which are also responsible for an increasing number of emerging zoonoses (Bordes et al., 2015).

Interventions to restore ecosystems or ecosystem functions, through the reintroduction of key species or through the concept of *free evolutio*n could also correspond to other examples of the “Ecohealth” approach (Roger et al., 2016; Morizot, 2020). The concept of *free evolution* promotes a "restoration" of ecosystems in the long-term by providing the minimum conditions to allow living things to express their own regenerative capacities (Morizot, 2020). Although the United Nations already recommends ecosystem restoration, a more radical approach is needed (Breed et al., 2020). Understanding the causal link between ecological restoration and health problems is essential, while causality is still difficult to establish when it comes to taking into account the inherent complexity of ecological systems (Terraube et al., 2017). Moreover, ecological restoration is often considered in the context of economic cost reduction rather than for ecological or health benefits. The policies envisaged must be a break with classical, coercive and exclusionary conservation, heir to colonization, and must be truly community-based conservation. Restoring a healthy environment in a sustainable manner for humans and non-humans constitutes a fundamental public health intervention.

4. Conclusions

Anthropogenic environmental changes, inherent in the capitalist socio-economic structure, have a fundamental role in the creation of pathogenic environments, the landscapes of emerging human infectious, as well as chronic, diseases. Changes in land use, through the transformation of areas previously predominantly forested and the homogeneization of living things, have led to major imbalances in ecosystems. These geographical areas, or ecotones, and these periods of change, or chronotones, are the scene of major epidemiological changes in terms of emerging infectious diseases (Bradley, 2004; Despommier et al., 2006). Indeed, if emergences always correspond to multifactorial processes, it is fundamental to highlight the major influence of environmental determinants in recent emergences and the current health crisis. Ecological and social ecosystems are characterized by dynamic equilibriums, and the disruption of these beyond certain thresholds has also led to threats to human life on a global scale (IPBES, 2020).

Recent changes in terms of causes of mortality and burden of different diseases seem to herald the advent of the third epidemiological transition characterized by infectious diseases, pandemics and treatment resistance (Harper & Armelago, 2010). Like the two previous epidemiological transitions, this transition seems related to the intensive agricultural system and land use pattern, and confirms the charactierization of our times as the *Plantacionocene*.

Until now, a significant portion of health funding has been dedicated to the fight against these infectious emergences through a curative biomedical approach and planning preparedness for pandemics and crises. In our society a reversal has taken place between health promotion, on the one hand, and the fight against diseases on the other hand. Conversely, we feel it is particularly important to highlight the health/disease continuum. This paper proposes that primary prevention and health promotion should be encouraged through the promotion of favourable social and ecological environments. As Mi et al (2016) affirm, to "enhance a revival of environmental and social determinants of diseases after period of reductionist approach of infectious epidemiology which highlighted only behavioural risk factor for diseases". Seeking to understand possible alternatives in the field of public health leads us to an approach based on an ecology of health focused on ecosystems and applying ecological and social alternatives (Karesh et al., 2012). Ecological and ecosystemic approaches to public health attempt to understand and mitigate environmental risk factors before reaching critical thresholds for ecological systems which lead to pathogen emergence, and to avoid the creation of pathogenic environments.

This “EcoHealth” approach starts from local community-based ecodiagnosis of the community members’ environment and their health issues and is followed by ecological and social proposals for dealing with the identified root causes of imbalances: "ecological thought also offers a rich entrance to understanding living systems, with its emphasis on connectedness and interdependence*”* (Horwitz & Parker, 2019, p.1). Such alternative approaches could bring together both a conceptual model and practical control methods within a complex ecosystemic understanding of health problems, applied differently according to local socio-ecological and health specificities. The concept of "EcoHealth" is seen as a promising foundation of a more equitable and resilient public health model.

Stopping deforestation, advocating living-based practices promoting the natural functions of ecosystems and the solidarity of interdependencies such peasant agroecology and free evolution of certain forested areas (Morizot, 2020) could slowly lead to a rebalancing of ecosystems, with the preservation of diversity of species and of relations and a process of reappropriation by indigenous communities. Taking into consideration and highlighting the knowledge and know-how of indigenous communities to take care of each environment according to local specificities, could also be the point of departure for “EcoHealth” work. Actions for ecological restoration of ecosystems will potentially be less stigmatizing for local populations than campaigns promoting cultural change, such as the prohibition of traditional hunting activities. Overall, they will be decided and designed by the indigenous populations themselves. Moreover, this bottom-up community-based approach will ensure the support and motivation of the populations, without all the efforts currently required to obtain acceptability following external interventions.

These approaches involve long-term work and need to be systematized. The current challenge is to scale up these approaches, particularly through the training of future health ecologists (Nguyen-Viet et al., 2015). Training that mixes ecological and ecosystemic approaches with public health approaches would enable the cross-fertilisation of these disciplines. In this way, connecting ecology and health provides frameworks for us to learn from and understand the nuances of context-specific ecologies, that will also yield corresponding context-specific solutions (Horwitz & Parker, 2019). More attention has to be allocated to "EcoHealth" fields, to promote *undone science* (Frickel et al., 2010) and to implement these alternative ecological and social proposals. Avoiding an extractivist mode of research through fostering of participatory research should be encouraged. The next step is the scaling up of ecosystemic and environmental health approaches both in practice and in conceptual and policy frameworks. This suggests both introducing public health as fundamental land use issues, inaugurating peasant agroecology, land use and conservation as fundamental public health issues, and developing coherent policies. These developments should be based on real ecological and agricultural transitions (Everard et al., 2020) and on the project of *a more-than-human health* (Kehr, 2020).

Such an analysis could also be helpful in the understanding and management of the current COVID 19 crisis (Everard et al., 2020). This has brought the world to a brutal and difficult halt. We could imagine a general and voluntary slowing down in good conditions based on the preservation of ecosystem functions, and regenerative capacities of the living, and on the strengthening of the welfare and social state as an emancipatory system. The awareness acquired through health crises can be the driving force behind a break with the current paradigm, in order to reduce the human footprint on the Earth. The recent report of Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) workshop about Biodiversity and Pandemics is a move in this direction (IPBES, 2020). Philosophically, these alternatives call for us to search in the turmoil of the ruinous ecologies of capitalism and economic growth, to invent other possible worlds, other relationships to the world. Inventing stories of rehabilitation and care for ecological and societal ecosystems, creating the conditions for collective survival in the ruins, finding allies to bring about a different world that is more resilient and sustainable, more desirable (Haraway, 2020).

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