Review Article

Infectious human diseases: Regions, habitats, threats, and mitigation strategies: The issues—Part II

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Abstract

Globally, vaccines against 47 infectious etiologic agents are approved by at least one regulatory authority as of December 2022. The numbers of viral diseases, infections caused by mycoplasma, bacterial and protozoal diseases, mycoses, diseases caused by parasitic worms, and other infectious diseases of unknown etiology run into thousands. Therefore, more vaccines are required to be developed to keep more populations disease free. Climate change and global increase in temperature may promote sea level rises and an increase in the intensity of rains, causing an upsurge in certain infectious diseases in regions of the human population and even causing movement of habitats. In societies where the expenditure on health as a percentage of gross domestic product is higher, people are more capacitated to tackle the treatment and spread of infectious diseases. As several of such conditions are zoonotic, well-planned strategies for controlling the spread would go a long way in the proper direction. Poverty and contagious diseases are infallibly linked. Major infectious diseases of poverty include tuberculosis, human immunodeficiency virus (HIV)/ acquired immuno deficiency syndrome (AIDS), malaria, measles, pneumonia, diarrheal diseases, and several neglected tropical diseases. The world is not yet unified in action to jointly work to contain the global problem of infectious diseases in every human habitat. There was a visible divide between and among the rich countries versus the developing countries regarding accessibility and deployment of vaccines against COVID-19 flu. To contain the spread of infectious diseases in the future, the whole world would have to work together, raising funds, strengthening epidemiological surveys, inventing effective vaccines, and vaccinating the eligible population, as also treating the infected with therapy in time, besides resorting to other preventive measures for overall human progress. The developmental efforts are to be pursued jointly and together to benefit all people, respecting the world as one.

Keywords: Anthropogenic factors, dense population, etiologic agents for infectious diseases, healthcare infrastructure, infectious human diseases, vaccines, zoonotic diseases

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INTRODUCTION

In Part I of our paper on infectious human diseases,[1] the aim was to identify the actors that circumscribed the periphery and the boundary of contagious ailments and the central regions of the world where microbial infection, nature, and the spread of transmissible diseases were more. In this part, the aim is to discuss the issues that need to be flagged and worked upon, to minimize the build-out of infectious diseases. In this context, the pathways are

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to identify the main factors that influence the rise in infectious diseases, human health budget expenditure across various countries, the nature of the disease-causing microbes, the methods of containing the spread of diseases by vaccination, and taking other interconnected steps to minimize the advancement of infectious diseases. Research and developmental aims, it is thought, would have to find remedies to invent and develop effective vaccines and therapeutic substances within a short period to fight the following epidemics.

Dynamic moving environment: impact of climate change and rise in human diseases

Humans live in a world where the environment and the climate are constantly changing, though quite slowly. There is an increase in the intensity of change during the current time, and multiple human activities have been flagged that have contributed to climate change. Thickly populated, industrially vibrant, and commercially intense trading regions remain warmer than thinly populated regions.

The World Health Organization (WHO) predicted[2] that between 2030 and 2050, due to climate change, some 250,000 additional deaths per year would happen. The deaths were likely to be attributed to certain infectious diseases like malaria, diarrhea, cholera, malnutrition, and stress from heat. There would be a perceived shortage of safe drinking water, sufficient food, secure shelter, and clean air. The developing countries with weak health infrastructure would be least able to cope without assistance. Climate change impacts the hosts, the pathogens, and also the transmission methods. Climate change is the long-term statistical shifts of the weather conditions around the average weather events observed over long periods. The pattern of infections, either vector-borne or food and water-borne or airborne, can substantially change, impacting human societies.

Consequently, human society must develop newer adaptation methods to combat the change. The Intergovernmental Panel on Climate Change in its Report[3] published on August 09, 2021 has stated that emissions of greenhouse gases from human activities have raised the global temperature by 1.1°C [between the period of 1850 and 1900]. The global warming up is anticipated to reach or exceed 1.5°C over the next few closer decades, measured from 2021. The global average warming up would be manifested in more increase in certain regions than others and would take time to average out uniformly at every place.

Climate change is anticipated to result in more production of clouds in certain regions than before, intensifying monsoons, accelerating, and promoting changes in rains in such areas, thereby increasing floods and making shifts in the start of rains, thereby necessitating changes in the strategies of preparedness, for facing excessive water flows in the flood-prone areas. There would also be regions where fewer clouds would reach, and consequently, there would be a rainwater shortage. Such changes would affect crop production and food availability and may result in shifts in specific regional disease patterns. Such changes, wherever drastic, shall promote human movement from one region to another merely for survival, and infectious diseases shall follow displaced human activities.

Temperature rise shall also result in more ice melting across the planet and cause a rise in sea level. If the sea level rises, there can be a change in the local freshwater wetland development and vegetation as well as in animal population, which can be catastrophic. However, it takes many years for such changes to happen. Preventive efforts to retard the rise in the earth's temperature by human activities need to be taken up by societies expeditiously.

The magnitude of climate variables would pose more challenges in some regions than others. However, a definitive correlation between changes in the climate variables and changes in health risks from infectious diseases does not yet exist.[4] However, with more research, it might be possible to ascertain, in advance in future years if and how the relationship may be derived.

Health conditions of citizens linked to annual expenses on the health budget

An efficient health infrastructure of a country is to effectively provide essential health services to its people. The infrastructure must have the competence to prevent diseases, promote health and respond to emerging threats, as well as chronic threats to ailments and illnesses of people. The components of efficient health infrastructure include the presence of a capable and qualified workforce; modern information systems and up-to-date data on ailments and diseases; an efficient system for diagnosis and investigation of health problems in the community education and information about health issues; development of policies and plans to for supporting multiple aspects of maintaining better health; enforcement of laws and regulations to protect individual and public health and to ensure safety in all aspects of deployment of therapeutics; create institutional structures for the conduct of research on multiple aspects of health issues and problems; and promote and keep a watch on the industry that provides diagnostics, therapeutics, medical instruments, and other services to the community. To create a more efficient infrastructure, individual countries must spend more. More

expenditure for health in a country is thought to be linked with more improved health infrastructure in that country.

Since in health emergency conditions, the affected individuals or their close associates have to tackle the situation initially by themselves, and they should have enough savings at their disposal. As all kinds of deteriorating health conditions can be better handled in hospital settings, innovative health services, including creating modern hospitals, should be available close to human habitats.

The health care expenditure as a percentage of gross domestic product (GDP) is a rough comparative measure of a country's attention toward the health of its people in comparison to other countries. GDPs are considered to be a comprehensive scorecard of a country's economic health, and higher per capita GDP values indicate comparatively better financial standing of the citizens.

The current health expenditure as a percentage of GDP in certain selected countries[5] was: China 5.35%; other selected poorer Asian countries like India 3.01%, Indonesia 2.90%, Pakistan 3.38%, Bangladesh 2.28%, Bhutan 3.61%, and Nepal 4.45%; Nigeria 3.03% and Kenya 4.59% among highly populated African countries; Brazil 9.59%, Mexico 5.43%, and Latin America and Caribbean countries 7.76%; Russia 5.56%, EU 9.92%; USA 16.77%, and Canada 10.84%. The health expenditure as a percentage of GDP of Asian countries as well as the African countries are low; those in Russia and Latin America and Caribbean countries are medium; while those in EU, as well as North American countries, are higher. The reasons for the existence of better health infrastructure in EU and North American countries are apparent. Consequently, people residing in these regions are better equipped to encounter infectious diseases. For the people living in other regions, the health infrastructure needs to be improvised and upgraded to minimize the impact of hazards emanating from infectious diseases.

Understanding and flagging major zoonotic diseases of the human

With the increase in the global population, the demand for animal proteins, eggs, poultry, and dairy products has increased sizably. To meet the growing demands, the infrastructure for maximizing production has also expanded. However, the infrastructures created in different countries have been different, some with high-class designs, but most built as low-quality outfits. These have resulted in increased contact of animals with humans. The demand for pets has also risen high in many countries, thereby promoting more human-to-animal contact. Migratory birds travel from one region to the other, carrying with them multiple types of diseases that can infect humans. Because of these factors, the probability of transmission of zoonotic diseases to humans has increased.

Several zoonotic diseases are transmitted naturally from vertebrate animals to humans or from humans to vertebrate animals; many such diseases are infectious. It is estimated that more than 60% of human pathogens are zoonotic in origin. Most humans, poor and rich, are in contact with animals in one way or another. Human is associated with many domestic animals, such as cows, goats, buffaloes, sheep, dogs, cats, horses, pigs, and others. Animals are domesticated for meat or milk, as beasts of burden, or as pets. Animals can harbor many diseases caused by viruses, bacteria, fungi, protozoa, parasites, and other pathogens. Presently, animal migration and trade, urbanization, climate change, and environmental change caused or influenced by people, vector biology, excessive travel and tourism, and other factors have greatly influenced the emergence and re-emergence of zoonotic diseases in humans.[6] There are several diseases caused to humans that emanate from avian species.[7] Birds such as chickens, ducks, pigeons, parrots, parakeets, turkeys, sparrows, crows, finches, and multiple kinds of migratory birds cause diseases in people. Disease transmission can be by direct as well as indirect contact and/or contact with insect vectors or other means. Major zoonotic diseases[8-10] of humans, coming from animals and birds, include anthrax, ancylostomiasis, avian influenza, avian tuberculosis, brucellosis, bovine pustular stomatitis, balantidiasis, campylobacteriosis, cryptococcosis, cryptosporidiosis, escherichiosis, erysipelas, leptospirosis, listeriosis, Q fever, rabies, rotavirus infection, tuberculosis, toxoplasmosis, toxocariasis, etc. The spread of such diseases can be minimized by resorting to basic hygienic practices.

Certain zoonotic diseases are linked with marginalized populations, and the link seems to be emanating from situations where such populations have little or no access to free services provided by the governments. Such situations arise from population movement or migration to areas where there is yet not much attention from the governments, like certain slum dwellers, geographically and/or politically marginalized populations, disasters made by a human thereby provoking migrations to nondeveloped areas, etc. Among zoonotic diseases in marginalized populations include different types of enteric infections; cryptosporidiosis; cysticercosis and taeniasis; Asian schistosomiasis; echinococcosis; foodborne trematodiases; toxoplasmosis; rabies; bacterial zoonoses; and others. While there is a considerable knowledge pool to effectively deal with these diseases, lack of interest, inadequate availability of funds, etc., come in the way of proper intervention.

WHO has identified and recommended several methods[11] such as expansion in the surveillance for zoonotic diseases in humans and animals; reassessing the burden of zoonotic diseases on the population; conducting community-led, more effective sanitation approach; and carrying out more research in public health, including veterinary and livestock services, addressing zoonotic diseases. Well-planned strategies for controlling the spread of zoonotic diseases would go a long way in containing and arresting the spread of infectious diseases.

Infectious diseases of the world affecting the poor the most

Poverty and infectious diseases are infallibly linked. Infectious diseases cause high morbidity and mortality. Such conditions not only cause ill health initially among the infected individuals, but the loss to a nation, expressed as disability-adjusted life years, is enormous.[12] Major infectious diseases of poverty include tuberculosis, acquired immunodeficiency syndrome (AIDS)/human immunodeficiency virus (HIV), malaria, measles, acute respiratory infection, pneumonia, and diarrheal diseases. Multiple neglected tropical diseases such as African trypanosomiasis, Chagas disease, Leishmaniasis, Lymphatic filariasis, Dracunculiasis ("Guinea worm disease"), Onchocerciasis, Schistosomiasis, and Trichomoniasis also cause high morbidity and mortality.[13,14] A region-wise brief analysis of poverty-linked diseases as narrated below reveals a similar picture in every poorer setting.

Southeast Asia

Over 85% of the total population of Southeast Asia reside in five countries, namely India, Bangladesh, Pakistan, Nepal, and Sri Lanka. In these regions, the poverty-related infectious diseases are not much different from other poor countries; there is a preponderance of certain diseases in these regions such as tuberculosis, diarrheal diseases, respiratory diseases, HIV/AIDS, mosquito-borne malaria, dengue, chikungunya, influenza, and others. In Bangladesh, the burden of acute respiratory infections among under-five children about household wealth and socioeconomic status was studied. The findings indicated a significantly negative association between adequate access to purer drinking water, hygienically improved sanitation setup, and use of firewood, animal dung, coal, kerosene, etc., which also contribute to acute respiratory infections.[15] Disease mitigation issues in these regions focusing on the most vulnerable groups including reducing stigmatization and discrimination about certain infectious diseases shall pay more dividends in minimizing and preventing the spread of multiple infectious diseases.[16]

Latin American and Caribbean regions

The infectious diseases of the poorest people of the Latin American and Caribbean region include those that continue to infect the deprived poor; a significant section of these populations include selected indigenous populations, people of African descent, and other disenfranchised poor. As in other poorer regions of the world, the diseases include tuberculosis, HIV/AIDS, malaria, dengue, schistosomiasis, leishmaniasis, trachoma, leprosy, lymphatic filariasis and several neglected tropical diseases such as hookworm infection, other soil-transmitted helminth infections, and Chagas disease. In these regions also, the strategy for containing these diseases needs to integrate intersectoral activities among public health mitigation strategies, social services for maintaining better human health, and sound environmental interventions.[17]

African countries

Africa is thought to suffer from about 24% of the world's diseases but has presently only 3% of the healthcare workers on the planet. The health infrastructure is very poor, the health professionals are too few (per 30,000 to 40,000 persons, only one medical doctor), health supplies are too few, and the poverty level is very high.[18] Among the 53 African countries, 34 countries are classified as low-income economies. In many African countries, where cities are rapidly expanding, creating newer opportunities for jobs and earnings, because of unplanned growth, slums are developing quite fast. The rise in the urban population in many African cities has been between 3% and 6% annually. Rural people have moved to cities in pursuit of newer earning opportunities. Disproportionate and unplanned growth of slums is creating more unique scope and undesirable elbow rooms for infectious diseases to flourish and spread. The outbreak of deadly diseases like Ebola, Zika, and other already prevalent contagious diseases like tuberculosis, HIV/AIDS, other multiple sexually transmitted diseases, malaria, dengue, chikungunya, cholera, typhoid fever, respiratory diseases, diarrheal diseases, and a host of neglected tropical diseases have taken a heavy toll of lives. The infectious disease burden is indeed devastating, causing not only heavy loss of lives but also causing disabilities, deformities, and loss of productivity.[19,20] Interestingly, there is a gradual fall in the number of extremely poor people globally over the years.[21]

It is evident that poverty and infectious diseases can go hand in hand, can undermine the resilience of societies, and can have devastating economic consequences in developing countries. The causative etiologic agents of infectious

diseases are viruses, bacteria, protists, fungi, and parasites, the spread of which must be prevented by intelligent, systematic, and sympathetic endeavors to benefit human health and thinking of the world as one.

More familiar human disease-causing infectious microbes, vaccines, and vaccination updates

It is obvious that to minimize the spread of infectious diseases, the use of vaccines, wherever available, would play an important role. In this context, it is useful to review the maximum number of infectious human diseases known to humankind that are more commonly encountered. Effectively tackling such diseases would require effective vaccines as well as efficacious therapeutic substances.

While searching, the more familiar disease-producing etiologic substances falling into the following categories were kept in view.

- DNA- and RNA-based viral diseases
- Infections caused by mycoplasma (cell wall lacking bacteria)
- Multiple bacterial diseases
- Protozoal diseases
- Mycoses or fungal diseases
- Helminths caused by worms
- Sleeping sickness caused by parasites
- Some other diseases of unknown etiology

Direct human-to-human contact causes the spread of a couple of diseases. Zoonotic diseases are transmitted majorly from vertebrate animals to humans. Several parasitic insects and arthropods like mosquitoes, flies, bugs, black flies, tsetse flies, sandflies, fleas, mites, lice, ticks, aquatic snails, centipedes, and millipedes also cause the spread of many human diseases.[22] Additionally, several harmful algal blooms can also cause considerable distress. Algal blooms occur in fresh waters like lakes and rivers as also in salt water such as in bays and oceans. On growth, algal blooms appear as foam, scum, paint, or mats on the surface of the water and can appear colorful. Several such blooms[23,24] can produce toxins that can cause sickness to people and animals. These were kept in view while searching for the etiologic agents.

From earlier literature, it was revealed that some 1415 microbial species were identified that cause infectious human diseases.[25] These included 217 species of viruses and prions, 538 bacteria and *Rickettsia* spp., 307 diseases caused by a range of different fungi, 66 by protozoa, and 287 diseases caused by parasitic worms or helminthiasis. However, the intensity and severity along with the spread of each infectious disease require to be known to develop plans for each region-specific remedy. It came out from a further search of literature that presently some 21 families of viruses are known to cause human diseases.[26] However, the most prevalent viral diseases presently encountered as assessed by the authors and reported in alphabetical order were: Adenovirus (human) infection; Avian influenza; Chikungunya; Coronaviral diseases; Dengue fever; Ebola hemorrhagic fever; Enteroviral (non-Polio) diseases; Flu (influenza) excluding avian influenza; Hantavirus Pulmonary Syndrome diseases; Hepatitis A infection; Hepatitis B infection; Hepatitis C viral disease; Hepatitis D virus infection; Hepatitis E infection; HIV-1 and HIV-2 infection; Human papillomavirus diseases; Japanese Encephalitis; Kyasanur Forest Disease virus; Lymphocytic choriomeningitis; Marburg viral disease; Measles; Monkey Pox; Mumps; Norovirus disease; Polio; Rabies; Respiratory syncytial virus illness; Rubella; Herpes; Simian foamy virus infection; Smallpox (variola major and variola minor); Varicella (Chickenpox) infection; West Nile virus disease; Yellow fever disease; and Zika virus infection. If one takes into consideration the multiple genotypes and serotypes among many of these viruses, the numbers to be treated would swell to over 350. In the case of bacterial diseases, it was observed that more than 60 bacterial families are human pathogens, and the enterobacteria and the mycobacteria are responsible for most of the diseases.[27] Of all the bacterial pathogens, 33 clinically most significant ones were identified which were responsible for the maximum number of deaths globally during 2019. The five bacterial pathogens namely *Staphylococcus aureus*, *Escherichia coli*, *Streptococcus pneumoniae*, *Klebsiella pneumoniae*, and *Pseudomonas aeruginosa* were found to represent[28] nearly 55% of all deaths caused by a bacterial infection in 2019. Here also if one considers the multiple serotypes, the numbers to be tackled, as assessed by the authors would exceed 460. Fungal infections in humans are increasing worldwide, causing many deaths.[29] More than 50 species of fungi are known to cause disease.[30] Opportunistic fungal diseases include[31] aspergillosis, mucormycosis, candidiasis, cryptococcosis, pneumocystis, and sporotrichosis. The major protozoan diseases[32,33] caused in humans include amoebiasis including *Sappinia* amoebic encephalitis, babesiosis, Chagas disease, cryptosporidiosis, giardiasis (lambliasis), leishmaniasis, malaria, schistosomiasis, toxoplasmosis, trichomoniasis, and trypanosomiasis. Many parasitic worms infect humans and animals.[34,35] These include roundworms (*Ascaris* and hookworms); pinworms (*Enterobius vermicularis*); tapeworms from beef and pork (*Taenia seginata*, *Taenia solium*, and *Taenia asica*); roundworms transmitting from animals to humans manifesting toxocariasis (*Toxocaria canis* and *Toxocaria cati*); whipworm (*Trichuris trichiura*); lymphatic filariasis caused by

three types of filarial worms namely by *Wuchereria bancrofti*, *Brugia malayi*, and *Brugia timori*; trematodes(flukes) including blood flukes, liver flukes, lung flukes, and intestinal flukes, caused by multiple trematodes. Over 80 different species of trematodes are known to cause human diseases.[36]

The periphery of infectious diseases in humans is indeed vast[37-41] and is ever-expanding, as new knowledge keeps pouring in.

To ascertain the updated knowledge about the number of vaccines discovered to contain some of these disease-causing microbes, an exhaustive search was made.[42-45] The study revealed that as of December 2022, there were vaccines against 47 etiologic agents as mentioned in Table 1, which were approved by one or more of the Regulatory Authorities from all over the world, to tackle the diseases emanating from the infectious etiological agents. Efforts are being made to develop vaccines against a couple of other disease-causing agents like the Chikungunya virus, HIV, Respiratory Syncytial Virus, Group B strep (*Streptococcus*) infection, and some others.

It is apparent at this point that containing a vast majority of infectious diseases is yet a far cry situation. The present global developmental situation calls for more research efforts to capacitate humankind to enlarge the spectra of fighting infectious diseases more effectively.

It is necessary to state that besides the strategy of tackling infectious diseases with vaccines, humankind globally has evolved multiple other strategies for containing these. Major efforts include inventing effective therapeutic agents, including antibiotics, synthetic drugs, and biological therapeutics; finding effective methods for the supply of safe drinking water; inventing more hygienic infrastructures for sanitation and better treatment methods of infective waste products; inventing safer dwelling places; and creating an improved social and stable political environment, besides others. All these measures combined have assisted in increasing the longevity of human beings. These aspects are not, however, the subject matter of discussion in this review paper. The focus is on identifying microbes causing infectious human diseases.

Disease-causing microbes comprising viruses, bacteria, fungi, protozoal parasites, and worms have threatened human health for centuries and will continue to do so

Table 1: Vaccines against infectious etiologic agents, in alphabetical order

Approved vaccines in alphabetical order (A to Z)	Name/s of the etiologic agent against which vaccines are available	Total infective etiologic agents
A	Anthrax; Adenovirus type 4; and Adenovirus type 7	3
B	BCG (Bacillus Calmette–Guerin)	1
C	Cholera	1
D	Diphtheria, Dengue	2
E	Ebolavirus; Enterovirus EV 71	2
H	Hemophilus influenza type b; Helicobacter pylori; Hepatitis A; Hepatitis B; Hepatitis E; Human papillomaviruses (Types 6, 11, 16, 18, 31, 33, 45, 52, and 58)	14
I	Influenza vaccine against type A; against type B	2
J	Japanese encephalitis	1
K	Kyasanur Forest Disease (Kerala, India)	1
M	Malaria, Monkey Pox non-replicating orthopoxvirus; Monkey Pox replication competent.	3
N	Neisseria meningitidis.	1
P	Pertussis; Polio; Plague; Pneumococcus	4
Q	Q fever (caused by Coxiella burnetii)	1
R	Rabies; Rotavirus; Rubella	3
S	Smallpox, SARS-CoV-2	2
T	Tetanus; Tick-borne encephalitis-European strains; Tick-borne encephalitis-strains Far-Eastern strains; Typhoid fever	4
V	Varicella (Chickenpox)	1
Y	Yellow fever	1
Total		**47**

Notes: The numbers of vaccines counted are for each etiologic agent. *Etiologic agents* = Infectious substances causing or contributing to the cause of a disease or condition. There could be multiple kinds of vaccines against each infectious disease-producing microbe. *Type* = A specimen (or a group of specimens) of an organism to which a scientific name is given to the organism. All vaccines against etiologic agents of one type are considered as one vaccine type. Each type represents a different etiologic agent against which vaccines may be required to be made for protection. *Variant/(s)* = A genome where there may be one or more mutations in the parent genome. In the case of COVID-19 flu caused by the SARS-CoV-2 virus, multiple variants exist. For convenience, the World Health Organization (WHO) and other public health organizations like the United States Food and Drug Administration (USFDA) use terms such as Variant of Concern (VOC), Variant Being Monitored (VBM), Variant of Interest (VOI), and Variant of High Consequence (VOHC) based on characteristics of microbes and their shared attributes. Such terms are often used to inform the public about the nature of the virus and the actions required to deal with such variants. All variants of the SARS-CoV-2 virus are considered as one etiologic agent with multiple subtypes

in the future. A couple of newer deadly diseases besides COVID-19 flu are increasing fast, and the spread of Ebola infection worldwide[46] is a glaring example.

With the application of new knowledge and well-planned strategies of surveillance systems as well as the prevention and treatment strategies using vaccination and treatment with pharmaceuticals besides others, there can be a considerable reduction in human deaths and economic losses.

DISCUSSION AND CONCLUSION

Presently, vaccines against 47 infectious agents are approved by at least one regulatory authority. More vaccines are required to be developed to keep more populations disease free. There are a few infectious diseases against which no cure is yet known, and the survival rate in such infections is extremely low. These include granulomatous amebic encephalitis (serious infection of the spinal cord and brain) and primary amebic meningoencephalitis (swelling of the membranes of the brain and the cerebral tissues). For several infectious diseases, if untreated, such as sleeping sickness, visceral leishmaniasis, HIV, Glanders septicemic disease, Machine alphaherpesvirus, Aspergillosis, Ebola virus disease, Marburg virus infection, Cryptococcal meningitis, Anthrax, Plague, some others, the fatality[47] is very high. Presently, malaria, tuberculosis, HIV, tuberculosis with HIV, diarrheal diseases, and acute respiratory infections are among the top infectious diseases worldwide.

To address the threats of emerging infectious diseases, Center for Disease Control and Prevention, USA recommended[48] a well-thought-out strategic plan, which included four goals, namely emphasizing strong surveillance, conducting applied research, taking steps for prevention and control, and improving the public health infrastructure. The future threats from emerging infectious diseases can be considerably minimized by innovative analysis and by working out more effective doable methods to address the above four goals.

The emergence of new infectious diseases seems strongly associated with human interaction with animals as the starting cause. The span of interactions constitutes habits of capturing, killing, and eating wild animal meats; the closeness of humans toward domesticated animals for milk or meat or collection of valuables such as fur and skin for use as leather products; keeping and nurturing domestic pets, etc. Usually, the new disease-causing agent gets transmitted to humans through the animals, which act as the zoonotic hosts. Sometimes, it becomes difficult to precisely pinpoint the intermediate zoonotic hosts, although the route of transfer of new infection through zoonosis seems firm.

Human infection of new and novel viruses for the first time, such as Ebola[49,50] in Africa in 1976; severe acute respiratory syndrome (SARS or SERS-CoV)[51] in China in 2002; Chapare virus in Bolivia[52] in 2003; Middle East respiratory syndrome coronavirus (MERS or MERS-CoV)[53] in Arab countries in 2012; Langya virus infection (caused by Langya henipavirus)[54] in eastern China in 2018; and the latest SERS-CoV-2 in China[55] in 2019, all seem to be linked with animals residing closer to human habitats, wild animals including those hunted for use as food, and domesticated animals used for multiple benefits. Human diseases causing severe microbial infection are strongly linked with the closeness of humans with animals. Vigilance is constantly required on animals that are around and can come closer to human habitats, human food, and multiple other human necessities including human companionship, to enable finding clues for new and emerging as well as existing infectious diseases.

Expansion in the surveillance for zoonotic diseases and intermittently reassessing the burden of zoonotic diseases on the population, conducting community-led more effective scientific sanitation approaches, and carrying out more research in public health, linked with veterinary and livestock activities would enable more effective control of zoonotic diseases. Well-planned strategies for controlling the spread of zoonotic diseases would go a long way in diffusing infectious agents.

Based on the emergence of viral influenza with the causative agent as H7N9 influenza (during 1999–2001 in Italy), SERS diseases (February 2003 in China and spreading to other countries) and MERS (during 2012 affecting several countries in the Middle East), it was argued that to contain the epidemic from such diseases multiple able countries with the WHO should partner and must work together to tackle the existing health inequalities, especially among the socially disadvantaged subpopulations, and the efforts should extend beyond the boundaries of stronger nations.[56] The recent pandemic resulting from the infection of the SARS-CoV-2 virus, however, did not show large-heartedness by the able countries toward the poor countries. Indeed, as soon as preventive measures were invented to fight against the recent pandemic created by COVID-19 flu, a large portion of all the available vaccines was captured and purchased by the wealthy countries, requiring the low- to middle-income nations to wait for their turn.[57] There yet exists a visible divide between and among the rich countries and rich people versus the poor countries with poor people in terms of

availability and deployment of targeted effective preventive agents and measures. The WHO decided[58] to vaccinate 70% of the global population to be vaccinated against SARS-CoV-2 viral infection in 2021, but as of June 2022, it could achieve the target only in 58 WHO Member Countries, while in low-income countries the situation was much dismal, and only 37% of healthcare workers had received a complete course, while for the general eligible public, the figures of the extent of vaccination were not available. It is presumed that the extent must be quite small in countries that cannot develop their vaccines, nor have enough funds to procure by purchase. This situation constitutes a serious threat to the poor people living in poor and economically weak countries. There is undoubtedly a need to improve upon the situation if equitable global human developments are in view.

The pandemic created by the COVID-19 flu had globally encouraged multifaceted collaboration among academic institutions, the private sector, and the government instrument (especially the regulatory infrastructure), to come out with products and services for use among people for containing the disease and becoming safe. As a result, multiple procedures and products were invented in a short time, which include adherence to simple, easy-to-do procedures for keeping away from infection, the development of protective equipment, several types of testing kits, respiratory devices for the treatment of critically ill patients, and trial of multiple therapeutic substances for treatment. New vaccines were invented in a record short time, and their applications on the citizens brought considerable respite to people all over the world, although in the meantime over 6.46 million people had died. In future years, therefore, more emphasis is to be put on the International Organizations, of which all countries are members, to work out jointly such strategies and actions that are most optimum to benefit every country rationally.

In a most recent initiative, a project was conceived in Australia with a cost of Aus$1.5-billion to look for technological remedies to create drugs within a very short period, within weeks or months of emerging pandemic threat.[59] Such initiatives taken by international agencies like WHO and others, with a bigger budget would go a long way in assuring the global human community with hopes to face the emerging pandemics.

The pandemic of COVID-19 flu has also taught us that for common people to remain safe during any epidemic, wherever vaccines are available, people should be immunized against the disease. In general, all people, especially the potentially susceptible ones, should avoid bodily contact with others, protect themselves from coughs and sneezes by using protective masks when they are in imaginably infectious areas, and wash and keep dry their exposed parts of the body intermittently when back from outside, keep the surfaces of their dwelling places clean by using appropriate cleansing agents, keep the residing places well-ventilated, prepare their foods safely, resort to safe practices so that the infectious diseases do not have the chance to transmit from close bodily contacts, and stay at home when they are sick. It is believed that the imposition of multiple nonmedical and nontherapeutic interventions (NM and NTI) to prevent the spread of infectious diseases, especially during the emergence of a pandemic would add to strengthening the capacity of a country to fight the situation, and for such purposes, well-thought-out plans and standard implementing procedures (SIPs) can be drawn out in advance for containing infectious diseases, emanating from spreading through the air, water, foods, and other external agents. Different kinds of infectious diseases such as respiratory diseases, gastrointestinal diseases, blood bore diseases, vector-borne diseases, zoonotic diseases, and sexually transmitted diseases would require different kinds of SIPs, many of which are already known. There is, however, a need to do more research to keep ready affordable SIPs for NM and NTI for the potentially more threatful infectious diseases. Educating the people about adherence to the SIPs in advance through media is anticipated to provide more mileage.[1]

In a study, based on the lessons learned from the first 15 years of the twenty-first century, a couple of indicators linked with infectious diseases have been highlighted, which include measures for reductions in child mortality; better control of vaccine-preventable diseases by using appropriate vaccines; reduction of a couple of infectious diseases by providing access to safe drinking water and setting up of scientifically sound sanitation system; considerable success in prevention and treatment of malaria, tuberculosis, HIV/AIDS and certain neglected tropical diseases by use of proper medicines and sound strategies, among others.[60]

Among the preventive measures, vaccines shall undoubtedly represent one of the most cost-effective ways of intercepting and warding off infectious diseases. The development of new vaccines is complex although multiple methods are already known. Classical methods use whole microbes as attenuated or deactivated or use microbial metabolites appropriately modified and used; subunit or recombinant antigenic proteins are isolated or made by rDNA technology and used; carbohydrate-based antigens made more immunogenic through tagging with immunogenic proteins; nucleic acid-based DNA or mRNA substances where antigenic proteins are translated and made to be exposed to the immune cells of the recipients; and such other methods rely on the effective interaction of a potent microbial antigen with the immune cells

of the vaccine recipients and to acquire competence to deal with the microbe through the Th-1 or Th-2 or both immunoprotective pathways.[43] The present-day knowledge of genomics with its various learning avenues has enabled faster identification of vaccine candidates from the knowledge of whole genome sequencing of a pathogen and applying a combination of genomic strategies for identifying the best genes and proteins or other antigens of interest for vaccine development in a shortest possible time. Every country should devote itself to setting up whole genome sequencing facilities or effectively collaborate with such set-ups and work for the development of newer and more effective vaccines to combat microbial disease. This strategy, a kind of synthetic genomic pathway, would be one of the best cost-effective strategies for dealing with infectious microbial diseases.[61,62]

The infectious diseases prevention strategies should have to include continuously imparting knowledge among the public for keeping away from diseases, resorting to extensive vaccination and treatment with effective drug substances (where vaccines and efficacious therapeutic interventions are known), conducting planned urbanization, taking worthwhile measures to contain the spread from zoonotic sources, strengthen surveillance strategies by simple, doable methods to detect pathogens that cause the disease, and identifying factors that contribute to it. Such stupendous tasks would require raising enough funds to work together through organizations that are global such as the WHO, with their offices evenly and rationally spread all over the different countries and agreeing to work together with the concept that the world is one.

In any given society, since in a health emergency, the affected individuals or their close associates have to initially tackle the situation, they should have enough savings at their disposal. As all kinds of deteriorating health conditions can be better handled in hospital settings, innovative health services should be available close by to the potential users. If, therefore, societies promote such policies that ensure higher individual income, higher individual savings, and fast access to their savings for making spending and have better health infrastructure close by, there is no doubt that the lifespan of such societies shall be longer. This partly explains why the longevity of people in rich countries is more.

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Conflicts of interest

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