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How urbanization affects the epidemiology of emerging infectious diseases

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The world is becoming more urban every day, and the process has been ongoing since the industrial revolution in the 18th century. The United Nations now estimates that 3.9 billion people live in urban centres. The rapid influx of residents is however not universal and the developed countries are already urban, but the big rise in urban population in the next 30 years is expected to be in Asia and Africa. Urbanization leads to many challenges for global health and the epidemiology of infectious diseases. New megacities can be incubators for new epidemics, and zoonotic diseases can spread in a more rapid manner and become worldwide threats. Adequate city planning and surveillance can be powerful tools to improve the global health and decrease the burden of communicable diseases.

Keywords: *urban infections*; *urbanization*; *zoonotic diseases*; *emerging infections*

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The industrial revolution in the 18th century led to larger cities with greater potential for growth and development both for the individual and the community. Living in a city can provide you with several advantages, such as the possibility for higher education, a new job with higher income, the security of better health care, and the safety of social services. In 2014, the United Nations estimated that 54% of the world's population, 3.9 billion, lived in urban centres (1). Economic growth for countries has been linked to urbanization and countries with high per capita income are among the most urbanized, whereas countries with low per capita income are the least urbanized (2). The financial and political power is often concentrated in the cities, which leads to unique possibilities for action and quick response if needed.

The process of urbanization refers to increased movement and settling of people in urban surroundings (3). However, the meaning of the word 'urban' does not have a universal definition. A wide variety of different interpretations can be found in various countries, and often they do not share the same understanding. Different versions could be: living in the capital, economic activities in the region, population size, or even density. The lack of a universal definition makes it hard to compare different countries and cities in regard to public health and the burden and impact of infectious diseases (4). Many of the studies conducted address the differences between urban and rural areas, and do not compare different urban settings. It can thus be difficult to get a global overview and get a better understanding of the burden of infectious diseases in these specific environments. Cities from around the world can also be very heterogeneous and the local diseases and health challenges can greatly differ. The challenges for one city can be completely different for another location (5).

About a century ago, only 20% of the world's population lived in cities, and in the least developed countries the percentage was only 5% (6). Approximately half of the world's population now live in these urban centres. The two inhabited continents, which currently are the least urbanized, are Asia and Africa, with respectively 48 and 40% of the population living in cities. These percentages are expected to rise dramatically by the year 2050 to 64 and 56% respectively (1). In the last decade, the growth in the urban population has been the highest in Asia, adding 0.88 million urban migrants per week. Africa was the second highest contributor with 0.23 million. The total figure of new urban residents per week during the last decade was on average 1.2 million. It is in Africa and Asia where the current rapid growth is taking place. In comparison, cities in the United States only grew 1% per year between 2005 and 2010. Projections for the next

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30 years are that almost all of the population growth will be in urban areas, but the growth in developed countries is expected to remain largely unchanged (2).

Chronic illnesses have been increasing in importance for the developing world. Worldwide the leading causes of death in 2011 were ischaemic heart disease followed by stroke, lower respiratory infections, chronic obstructive lung disease, and diarrhoeal diseases. However, if you look at the list for low-income countries, infectious diseases still have a profound impact. The top three causes of death in these settings are all infectious diseases: lower respiratory infections, HIV/AIDS, and diarrhoeal diseases (7). Many of the lower income countries are expected to have a major growth among the urban population, which leads to considerable challenges for the governments and health care to keep up to pace and develop their social services and health care as these regions grow.

The rise of the new modern cities also creates potential risks and challenges in the aspect of emerging infectious diseases. Different risk factors in the urban environment can, for example, be poor housing which can lead to proliferation of insect and rodent vector diseases and geohelminthiases. This is connected to inadequate water supplies as well as sanitation and waste management. All contribute to a favourable setting for both different rodents and insects which carry pathogens and soil-transmitted helminth infections. If buildings lack effective fuel and ventilation systems, respiratory tract infections can also be acquired. Contaminated water can spread disease, as can poor food storage and preparation, due to microbial toxins and zoonoses (2). The density of inhabitants and the close contact between people in urban areas are potential hot spots for rapid spread of merging infectious diseases such as severe acute respiratory syndrome (SARS) and the avian flu. Criteria for a worldwide pandemic could be met in urban centres, which could develop into a worldwide health crisis (8). Adequate city planning can be a key factor for better overall health, and such considerations must be in the mind of the governing bodies.

Today's megacities are very heterogeneous with large slum settlements, which lead to challenges for overall health and health care in the community. Within one large urban setting, there can be huge differences in health conditions depending on where you live. In general, the urban health is better, but in some areas, it can actually be worse compared to certain rural environments (8). Of the estimated 3 billion people living in urban centres, about one-third live in slum areas (9). The ever-changing environment of cities has made certain infectious diseases both emerge and re-emerge. Pathogens which adapt to urban environments from rural settings can spread in a more rapid manner, and be a greater burden to the health care services (2).

This review article examines the urban world and how the current rapid urbanization around the world is affecting the epidemiology of emerging infectious diseases. Currently the most rapid growth in urban population is taking place in the developing countries, and poses many different challenges compared to traditional high-income countries. This review focuses on these growing regions and their implications and how emerging infectious diseases affect the community.

Urban population – a heterogeneous group with different living conditions

Cities around the world can look very different if you compare the living conditions for the residents. However, it is not only different cities that can have completely diverse standards of infrastructure and social security. The same city can provide very varying conditions for their residents. Living in the slums compared to more wealthy neighbourhoods, will expose the inhabitants to different risks. Traditionally cities can offer many advantages compared to rural settings, but under certain circumstances they can rather be a health hazard. The rapid migrations of people to cities can lead to overcrowding, which can generate slums or shanty towns. These slums are characterized by poor housing, lack of fresh water, and bad sanitation facilities (2). All of these shortages can be a threat to the residents' health and be a possible breeding ground for infectious diseases. The location of slums are often outside of the city centres, in more hazardous locations and the population feels a lack of social and economic opportunities compared with other residents. In sub-Saharan Africa, 62% of the urban population in 2012 lived in shanty towns (2). For example, in 2009, 96% of the urban population in Central African Republic lived in these slums (6). In Kenya's capital Nairobi, 60% of the population lives in slums, and child mortality there is 2.5 times greater than other parts of the city (9). The community and health care services have great challenges to provide the entire population with equal and adequate service. The collected parties need to be aware of the differences in threats with respect to infectious diseases, both at the local and governmental levels.

Certain infectious diseases have been shown to be more widespread in the slums. An example of this is the diarrhoeal disease cholera. Infections have been linked to slums in Dar es Salaam, Tanzania, with high population density and low income (10). In several other countries, cholera incidence is the highest in urban regions with high population density (11, 12). Differences in prevalence of asymptomatic carriers of antimicrobial drug-resistant diarrhoeagenic *Escherichia coli* have also been found in Brazil between slum settlements and more wealthy parts of the community 13). The poor infrastructure in the slum can be a barrier for improvement, but at the same time targeted interventions for safer water and better sanitation

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facilities could potentially have a profound effect of the overall health.

Overcrowded housing in high-density populations in the slums can be a breeding ground for infectious diseases such as tuberculosis. The rate of tuberculosis has traditionally been higher in urban centres compared to rural (14, 15). Studies in slum settlements in Dhaka City, Bangladesh, indicate a high prevalence of tuberculosis, which was almost twice as high compared to the overall national average and four times higher than the overall urban levels (16). However, different patterns can be seen in different countries; for example, in Poland the rates of tuberculosis have shown only slightly lower incidence in rural population compared to urban, 21.9 per 100,000 versus 22.4 per 100,000 respectively (17). Tuberculosis in the United States has declined in the twentieth century, and several factors such as improved nutrition status, socioeconomic status, overall public health, and new drug regimens have been thought to play a major role. However, in the mid-1980s a resurgence occurred which reached its peak in 1992, especially in urban areas among the homeless and incarcerated population (18). The knowledge regarding symptoms, transmission, and prevention has been shown to be greater among the urban population in Pakistan's Punjab province compared to the rural population. Health-seeking behaviour was also better among the urban population, in the aspect of when to seek medical advice for early diagnosis and potential treatment (19). Information about infectious diseases and how they spread in the community can help the individuals to protect themselves, but knowledge about the slums and the infectious diseases panorama is also crucial for local physicians. They need to know how to look for the correct diagnosis, even if their diagnostic tools might be limited. The right hypothesis from the start in these cases is even more important.

City planning

The rapid urbanization around the world leads to great challenges in city planning. The rapid influx of migrants can lead to overcrowding and local governments might not be able to provide safe housing, drinking water, and adequate sewage facilities, all of which are potential health hazards and must be taken into account for safe city planning.

Today more than half of the world's population, almost 4 billion people, have access to piped water connected to their homes. Since 1990, well over 2 billion people have gained improved drinking water facilities, and almost 2 billion people have access to improved sanitation. However, more than 700 million people still lack access to improved sources of safe drinking water, and in sub-Saharan Africa half of the population lack such facilities. Globally the decline of open defecation between 1990 and 2012 went from 24 to 14%. However, 1 billion people in the world still practice open defecation. In this group, 90% live in rural areas, but the actual amount of residents from urban settings is gradually increasing. Between 1990 and 2012, the group in urban settings which lacked sanitation actually significantly increased from 215 million to 756 million, which could be explained by population growth (20). Much of the hard work to improve sanitation facilities has benefited large population groups, but the rapid influx of new urban residents shows that there is still much hard work to be done.

Residents who are subject to overcrowding and who lack access to safe drinking water or proper sanitation can be more susceptible to soil-transmitted helminths (21). These infections are among the most important causes of physical and intellectual growth retardation in the world and have a major impact on public health (22). Good hygiene practices and good sanitary conditions have lowered the prevalent levels of contamination. In the Brazilian city of Salvador, with a population of 2.5 million, an improvement of sewerage coverage from 26 to 80% of the households led to an estimated overall reduction of diarrhoeal diseases of 22% (23). Neglected tropical diseases can cause substantial health problems in developing countries, and some of these diseases have a faecal-oral transmission pathway. Examples of such diseases could be schistosomiasis, trachoma, and soil-transmitted helminthiases. Improved sanitation could contribute to a significant improvement for the public health. In many countries, however, the focus is on treatment by medication and not improved sanitation. The reason could be that it would be much more expensive to carry out the necessary infrastructural improvements (24). Safe drinking water and proper sanitary facilities must be taken into account in city planning. Factors like this can potentially have a profound positive effect in lowering infectious diseases with a faecal–oral route. However, the real challenge lies in the uncontrolled growth of slum settlements.

Poor housing and overcrowding can also contribute to vector proliferation. One example of this is for Chagas disease, which is a parasitic infection caused by the protozoan *Trypanosoma cruzi*. An important mode of transmission is vectorial infected bites of triatomine bugs. Living in close contact to domestic animals and poor hygienic habits have also been identified as risk factors (25). Chagas disease affects an estimated 8 million people every year, and is an important health challenge in Latin America. In recent decades, progress has been made to reduce the burden of disease, by vector control, screening blood donors, improved housing, and epidemiological surveillance. Chagas disease is a growing health problem in non-endemic areas because of population movements (26). It is estimated that 300,000 individuals in the United States are infected (27) and the most affected country in Europe, Spain, is thought to have 45,000–67,000

cases (28). The example of Chagas disease shows that physicians who practice in countries where the disease is not present must be aware of the travel history of the patient to connect the potential symptoms to the correct diagnosis.

The environment in urban cities has proven to be favourable for the rat population (*Rattus* spp.) and close encounters between rats and humans can lead to transmission of zoonotic infectious diseases. They can carry pathogens such as *Yersinia pestis*, *Leptospira* spp., *Rickettsia typhi*, *Streptobacillus moniliformis*, *Bartonella* spp., Seoul hantavirus, and *Angiostrogylus cantonensis* (29). New York City has one of the largest populations of rats in the United States. It has been shown that encounters between rats and humans have been linked to proximity to open public spaces and subway lines, the presence of vacant housing units, and low education of the population (30). Information like this can be useful for health officials when they launch specific control initiatives. The changes in human population with increased urbanization and urban poverty has also altered our perception of some zoonoses linked to the rat population. Leptospirosis has traditionally been perceived as a primarily rural disease, but the incidence in urban centres is increasing (31, 32). In Chinese cities, the incidence of Seoul hantavirus haemorrhagic fever with renal syndrome has been linked to urban growth, growing rat population, and increase rat–human contact (33). Large megacities all over the world have large rat populations, but the surveillance and local knowledge seem to be inadequate. A better understanding of how to prevent uncontrolled growth in rat population can potentially lead to a decline of these zoonotic diseases.

Traditional rural infectious diseases turn urban

The growing trend of urbanization around the world has shifted some infectious diseases, which have traditionally been perceived as rural, to urban settings. The World Health Organization (WHO) has published a list of 17 neglected tropical diseases. Several of them have now become a reality in the urban environment, these diseases are something the practicing physicians in these areas have to be aware of (34). Many of the diseases on the list are present in the developing world, which sometimes lack the opportunity to solve these problems by themselves. These countries need help from the global community.

One of the neglected infectious diseases is lymphatic filariasis (LF) with 2 billion people at risk, and 394.5 million in urban areas. One of the main reasons is the lack of proper sanitation facilities (35). LF still has its major impact in rural settings, but the increasing urbanization in the developing world has made LF an infectious disease that also has to be considered elsewhere. One of the parasite species *Wuchereria bancrofti* has been located in many urban areas and has the potential for transmission in this environment. Moreover, one of the vectors for the parasite is the mosquito *Culex quinquefasciatus*, which thrives in these surroundings, especially in overcrowded areas with poor sanitary and draining facilities. However, within one city the transmission can vary substantially depending on the standard of the sanitary conditions. The mosquito vector *Culex* spp. can be found in large parts of Central and South America, East Africa, and Asia (36).

Another vector which has adapted to urban surroundings is the mosquito *Aedes aegypti*, which is a key component for dengue transmission. Dengue is on WHO's list of neglected tropical diseases, and is on the rise worldwide. The number of infections has drastically increased in the tropical regions of the world in the last 40 years. Recent studies have estimated 390 million cases each year, and the burden is the highest in India with one-third of all the new infections (37). Several factors have played a big role in the escalation, such as urbanization, globalization, and lack of mosquito control. *Aedes aegypti* lay their eggs in artificial water containers made by humans, which is a key component in the urban transmission cycle. The adaption of dengue through its vector has made dengue an infectious disease on the clear rise (38). Thailand is a country with all four serotypes of dengue virus, and the epidemics of dengue haemorrhagic fever have shown a possible correlation to originate from the urban capital of Bangkok and then spread geographically in an outward manner to more rural settlements and provinces. A model to understand this mechanism could lead to more effective use of the health systems in the affected areas (39). Dengue has become a global problem and is no longer restricted to the developing world. Despite better knowledge, it seems tough to control the vector, which has adapted to the urban environment and living close to people. An efficient vaccine is not yet commercially available, but could be a powerful factor in the fight against the global dengue epidemic.

Often several different factors need to be favourable for a vector-borne disease to adapt to the conditions in an urban environment. For example, West Nile virus (WNV) infection is an infectious disease which has become a reality in the urban environment. The primary vector is the mosquito *Culex Pipens*, which lay their eggs in water resources which are often man-made. However, for a successful transmission cycle WNV also need the American robin (*Turdus migratorius*), which has several broods per season and hatchlings are more susceptible to WNV infection than adult birds (40). The county of Dallas, Texas, experienced an epidemic of WNV infections in 2012. Surveillance reports revealed 25% of the cases in the United States were found in Dallas County (41). It shows for a vector-borne disease to have a successful transmission cycle several different factors need to be in place to affect the human population.

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Leishmaniasis is a disease caused by the protozoa *Leishmania,* which affects 12 million and threatens 350 million people in 88 different countries. There can be different clinical presentations such as cutaneous and visceral (42). Leishmaniasis is transmitted by the vector phebotomine sandflies. When rural migrants bring their domesticated animals to urban settings, often slums, they create favourable conditions for an urban transmission (43). It has been shown that it is a growing health problem and the ongoing urbanization has contributed to the increase (44).

If the different vectors can adapt to the urban environment and man-made resources, the potential health implications can be of major concern. Control programs and adequate surveillance is of importance, but in rapidly growing cities and slums it can be tough to implement such measures. Emerging infectious diseases can also make the jump to stable transmission in the urban surroundings and surveillance of these can potentially prevent major health concerns and high cost for the health care services. WHO can play a major role in the fight for better control and knowledge. Many of the countries in the developing world do not have the proper resources and the problem is not concentrated to one region, but is a global concern.

Numerous of the neglected tropical diseases play a major role in the developing world, which is currently experiencing a much faster pace of urbanization compared to the developed world. The WHO's call for help is important and, for example, dengue is now turning into a global crisis. Safe and targeted assistance can be a huge factor for overall health; such assistance could be an effective vaccine or safe and easy vector control programs.

Modern cities a catalyst for rapid spread of infectious diseases

Urban centres can be catalysts for rapid spread of infectious diseases. The basis of large population groups in a restricted area can provide the perfect conditions for different epidemics. International travel has connected the world in the last century, and this mobility creates a potential threat of many emerging diseases. International tourist arrivals have shown an exceptional growth from 25 million in 1950 to 1,087 million in 2013. According to the latest forecast from the World Tourism Organization, international tourism arrivals will continue to increase, and in 2030 the figure is expected to be 1.8 billion (45). With the pace of modern travel, highly contagious infectious diseases can be a potential threat in a completely different setting compared to the original outbreak. Urban population and the density of residents can meet the criteria for a new epidemic and create a public health disaster, if not taken seriously.

International trade and travel can potentially also contribute to the occurrence of a worldwide pandemic. SARS emerged as a global threat in 2003. SARS is thought to originate from the SARS-like coronavirus (SCoV) of bats and reached the human host in China due to hunting and trading of bats for food (46). The disease was first recognized in wildlife markets in Guandong, China. Investigations have found this SCoV from the Himalayan palm civets in live-animal markets in the region. The first cases of SARS reportedly occurred in individuals who handled these animals to prepare exotic food, and the virus is thought to have crossed over to their human host (47). SARS could then spread throughout the world by, for example, international travel. It spread in urban dwellings in large cities and in well-equipped city hospitals. Public fear of travelling led to considerable economic losses that affected entire countries (48). The example of SARS shows that food markets in southern China can be the origin of a worldwide health crisis. Travel routes around the world have connected the urban world and large megacities like never before. Accordingly it is important to take necessary preventive measures before the epidemic gets out of control, and here big organizations like WHO, but also governments, play an important role. Early action is of utmost importance, and functional surveillance programs needs to be in place.

The zoonotic disease dengue is endemic in most tropical and subtropical regions, which often are also popular tourist destinations. Travellers to endemic countries can contribute to the spread of the disease. The burden of disease is on the rise, and estimations are that in returning travellers from Southeast Asia, dengue is now a more frequent cause of febrile illness compared to malaria (49). Dengue is now an urban health problem, which is one of the major reasons why the rise is exceptional.

The global rising problem of antibiotic resistance has also been linked to international travel. The worldwide spread of certain antibiotic resistant *Staphylococcus aureus* has been linked to tourism, which shows the potential impact on international health (50, 51). Faecal colonization with ESBL-producing *Enterobacteriaceae* has also been linked to international travellers in several studies (52–54). The physician needs to take into account the recent travel activities of the patient to better evaluate the current condition and need for potential treatment and care.

Global travel shows no signs of decline and the interconnected megacities around the world make global surveillance even more important when it comes to contagious infectious diseases. Measurements to stop the spread need to be taken at the original location, but knowledge about the specific disease needs to be passed on to the global community and local health workers in other parts of the world. This global surveillance and alert system needs to be fast and efficient to, if possible, reduce the impact. The expected rise of travel makes it critical for the future global health and the possibility to react in time for possible threats.

Zoonotic disease a challenge for the future

Rapid and sometimes uncontrolled urbanization can, in certain circumstances, lead to closer encounters with wildlife. Human influence on the ecosystems creates meeting points for new and potential zoonotic diseases, which could have a profound impact for both local and global health. The global trends of urbanization push people to previously untouched ecosystems. New housing in the outskirts of big cities can potentially be meeting points for new and already known zoonotic diseases. Of 335 emerging infectious diseases, which have been recognized between 1940 and 2004, more than 60% have been zoonotic diseases (55). Living in close contact to domesticated animals and hunt for '*bush-meat*' can also be risk factors for an infectious disease to make the jump from the animal host to humans. Major deforestation creates closer contact between humans and bats and even primates, who can potentially be host for '*new*' viruses. A better understanding, surveillance, and prevention of zoonotic diseases would be of great value, to both prevent and manage this upcoming threat for global health. Hot spots for this transmission have been found and they often correlate where the process of urbanization is on the clear rise (56). Even if it is not always the urban population who is at the front of new encounters with wildlife, it can still have an effect on urban health. The trend of people moving to cities are at the highest, where many of these new encounters with ecosystems take place, and infectious diseases can be introduced to these growing urban environments. The sometimes uncontrolled growth of cities pushes residents to untouched ecosystems when new housing expands.

Ebola virus disease (EVD) has had a profound impact on the world in 2014. Since the spring of 2014, the world has witnessed an unprecedented epidemic of this zoonotic disease. The hub of the epidemic has been the three countries in Western Africa: Sierra Leone, Liberia, and Guinea. It all began in December 2013 in Guinea, in the providence of Guéckédou, in the eastern rainforest region. The disease transmission in the capital of Conakry is thought to be the first major urban setting for EVD (57). WHO was first notified of the EVD outbreak in March 2014, and on August 8, the WHO declared the current situation as 'public health emergency of international concern' (58). Before, EVD outbreaks in central Africa had been limited in size and geographical spread to a few hundred persons, mostly in remote areas and not large urban settings (59). The centre of the epidemic (Guinea, Liberia, and Sierra Leone) has, as many of their neighbouring countries, a large population living in rural settings; only 36, 49, and 40% of their population live in urban centres (60–62). The population is, however, highly interconnected in these countries with travel and cross-border traffic, with good road access between rural and urban settings. These communications have made the magnitude of the EVD epidemic possible. Despite cases of EVD in Nigeria and Lagos, a megacity with 20 million inhabitants, the transmission has been limited, which proves that implementation of control measures can limit the transmission (63). The mortality rate has been high in previous outbreaks, up to 90% (64). The fatality rate in the West Africa epidemic has been estimated to around 70% for Guinea, Liberia, and Sierra Leone when data for patients with recorded definitive clinical outcomes (63). This unprecedented epidemic points out the importance of better surveillance, understanding, and preventions measures for this potentially deadly virus. Ebola virus (EBOV) is thought to be a zoonotic disease, and fruit bats are under investigation to be the natural reservoir. EBOV sequences have been found in these animals near the human outbreaks which implies where the virus might originate from (65, 66). Closer contact with humans and fruit bats are thus risks for a new global health crisis and the severity of an Ebola epidemic has already been witnessed. The high costs, both from an economic and overall health perspective, have affected entire countries and have even cost lives on the other side of the earth.

Urbanization and the urban environment a cause of better health

Urban centres offer their residents greater possibility for health and social services. Different factors, such as education, direct primary care services, and the governments' capacity for rapid response to upcoming health threats, can contribute to the opportunities in a city. However, in many cities the poor can find it difficult to access proper health care, due to the cost of such services. In more rural areas, the problem can instead be the distance to the nearest clinic, which in reality makes it impossible for prompt and efficient treatment (2).

Malaria has historically been and is still a major health concern in large parts of the world. WHO estimates 198 million cases (124–283 million) of malaria and 584,000 deaths (367,000–755,000) in 2013. The highest mortality rates have been shown to be closely linked to poor countries with a low gross national income (GNI) per capita (67). Estimations have been made that nearly 25% of the total African population, 200 million, currently live in urban settings where malaria transmission is a reality. The annual incidence is estimated at 24.8–103.2 million cases of clinical malaria among the urban population in Africa (68). The relationship between the malaria mosquito vector and the human host determines the burden of morbidity and mortality. This interface is dependent on many different factors and the degree of urbanization is an important one. A significant reduction in malaria transmission has been observed over the last century. Increased urbanization and decreased transmission have correlated in several different studies (69). However, whether it was the increased urbanization that led to a

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reduction in transmission or the malaria reduction that led to development that promoted urbanization of societies is a challenge to determine (70). A clear connection has been shown between reduced transmission of *Plasmodium falciparum* and urbanization; however, for *Plasmodium vivax* it is less obvious. For *P. vivax*, a connection has been found globally and in Asia and Africa; inconsistent results, however, were found in the Americas. Several possibilities could explain these incoherent results, such as more widespread transmission of *P. vivax*, lower transmission intensity, the wide distribution in Asia, and high prevalence of Duffy negativity in Africa, which protects against *P. vivax* (71). The overall decrease of the burden of malaria has been a positive effect of urbanization, but the exact mechanisms are not yet known. However, it seems that urbanization can have a favourable influence.

Immunization status between residents in urban centres and rural areas can differ. Coverage of measles vaccination in Indonesia have shown to be 68.5% in rural areas, compared with 80.1% in urban regions (72). Studies in Nigeria have shown that sometimes the coverage can actually be better in more rural areas, and it might be explained by better mobilization and participation in the delivery of immunization services (73). In a study in Uganda, 58% of the urban group compared to 53% in the rural areas were fully immunized, but polio vaccine was given to 51% in the urban group and 52% in the rural group (74). Immunization coverage can also vary considerably among different settings, not only between rural and urban surroundings, but also between urban, rural, and slum settlements. In Changdigarh, a union territory of India, full immunization of children at the age of 2 was 30% in slums, 74% in urban, and 62.5% in rural settings (75). It shows that there can be a wide variety of reasons for immunization status among the population in different regions and countries of the world. Effective immunization can be a cost-effective measure in poorer countries. High coverage can prevent epidemics in large cities and save many lives; however, immunization needs to be available both for the rural and urban population to achieve the greatest benefit.

A study in Tanzania has compared the knowledge about certain zoonotic diseases among general practitioners in urban and rural areas. The rural practitioners had poor knowledge of how sleeping sickness is transmitted and clinical features of anthrax and rabies. Laboratories in rural areas are often poorly equipped and cannot always diagnose certain zoonotic diseases, which could limit the doctors' capability for correct diagnosis and treatment (76). Public knowledge about certain infectious diseases can also vary depending on many different factors. The knowledge about sexually transmitted diseases (STIs) among Bangladeshi adolescents was higher among people in urban areas compared to rural, both in general and HIV and AIDS (77). The same results about HIV and AIDS have been found among a Canadian population (78). Studies in Chengdu and Shanghai, China, have shown risk perception about STIs and HIV and AIDS is profoundly changed in rural-to-urban migrants (79, 80). The same result has been shown in a study among rural-to-urban migrants in Ethiopia 81). The rapid influx of migrants moving to cities makes it hard to get adequate information to all the different groups in the society. To educate the public is one of the many challenges for local governments and health officials.

Campaigns to improve the public knowledge are useful to fight the threat of infectious diseases. Residents need to be aware of symptoms of infectious diseases to gain knowledge about when to seek health care and when it is safe to treat yourself. Knowledge about food storage, waste management, vector control, and sanitary facilities are all aspects that can lower the burden of communicable diseases. These campaigns can sometimes be easier in the urban environment because of the density of the population.

Conclusion

Urbanization is an ongoing process in the world at the moment, but the pace of the process is not universal. The developed countries, which have traditionally been thought of as high-income countries, are already urbanized, and it is in the developing world that the rapid rise is taking place. Infectious diseases still have a big impact on the global health, and urbanization is now altering the characteristics of these diseases. Living conditions in cities are overall better in urban environments compared to rural settings; better housing, sanitation, ventilation, and social services all play an important role in this improvement. Certain pathogens can, however, adapt to the different conditions and thus create a new challenge for both local governments and the global community. The capacity for surveillance, control programs, prevention, and public knowledge programs is far better in cities. It is here where the resources and political and financial power are gathered. But some countries do not have the resources and because these diseases can be of global concern, it is also the international community's responsibility to help and support with knowledge and resources.

The rapid urbanization has also interfered in previously untouched ecosystems. These new settlements create new and closer encounters with wildlife, which can be a potential source of zoonotic diseases. These can be both previously known or new pathogens, which make the shift from their animal host to generate infections in humans. Surveillance is of primary importance to monitor the burden of disease and will give both local authorities and the global community a chance for a quick response to public health threats.

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