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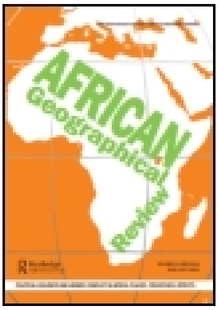

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RESEARCH ARTICLE

The global health threat of African urban slums: the example of urban tuberculosis

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Urban slums in developing countries are experiencing the most rapid population growth of any settlement type globally. Such growth of densely settled slums exerts a profound influence on the epidemiology and geography of communicable disease, transmitted through multiple modes. Specifically, high density, poor sanitation, poorly built housing, and lack of both adequate sewage systems and water supply facilitate pathogen spread. Long-range transmission of infection, partly through migration or travel of infected individuals, makes communicable diseases of urban areas in developing countries health problems of the entire world rather than localized areas. Non-endemic areas are threatened with disease spread. Because a significant proportion of slum growth and disease burden is in sub-Saharan Africa, global well-being demands that we understand and control disease spread in African slums as a major international health priority. This paper outlines the potential threats and implications of African urban slum health using the example of tuberculosis (TB), which is highly prevalent in developing countries. Using the case of Nima, a slum in Accra, Ghana, we argue that successful disease control efforts in developed countries depend critically on effective disease surveillance and control efforts in developing countries, including African urban slums.

Keywords: global health; urban health; slum health tuberculosis

Introduction

Urban slums have some of the worst health indicators of any settlement type. Moreover, the most rapid population growth globally is in urban slums in developing countries. Because of international migration and travel, Africa's rapidly growing urban slums threaten global public health. Pathogens move mostly with infected individuals, and greater transportation connectivity, forced and voluntary migration, and travel to and from developing countries – all facets of the broader phenomenon of globalization – facilitate the global traffic of pathogens to a degree that has never been seen before. Empirical studies of a number of diseases and a plethora of models confirm that greater population density promotes rapid local spread of communicable diseases (Thomas & Weber, 2001). Rapid spread is greatest in the case of diseases transmitted via the respiratory route, and this has been confirmed using both statistical models characterizing the past and present, and validated mathematical models that predict the future (Anderson & May, 1992; Meng, Wang, Liu, Wu, & Zhnog, 2005). African urban slums,

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like slums in other developing countries, therefore, provide ideal settings for communicable disease spread. Slums are also reservoirs and incubators – 'magnets' – of communicable disease, regardless of the mode of transmission.

Paradoxically, despite their pivotal roles in determining the disease burden in developing countries we have minimal understanding of slum health and the transmission dynamics of communicable disease within slums. In the absence of this understanding, effective methods of disease control are severely limited. Because of transportation interconnections and migration – manifestations of globalization – rapidly spreading communicable diseases in local areas anywhere may constitute threats to the health of populations elsewhere, including much of the globe (Relman, 2010). Slums, like the urban areas in which they are located, are integrally involved in the process of globalization, and there are flows of commodities, capital, and people between slums and remote areas in other parts of the world (Pieterse, 2011). Where there are flows of people, there is also the potential for pathogen spread. Consequently, it is critical that we develop better methods for interrupting disease spread at a variety of scales in developing countries.

This paper outlines the potential threats and implications of urban slum health in sub-Saharan Africa using the example of tuberculosis (TB). Globally, tuberculosis is second only to HIV/AIDS as a cause of death due to infection (WHO, 2013). Moreover, it is both an immediate and a contributing cause of death via HIV/AIDS. Uncontrolled TB spread in urban slums in Africa and elsewhere does not remain confined to slum areas. It spreads easily to other portions of a city, based upon contact patterns and daily movement. Thus, TB spread takes place at numerous scales: person to person; household to household; one portion of a slum to another; from slums to other portions of the city; from those areas to other nations and to rural areas; and from nation to nation. When President Bill Clinton declared in 2000 that HIV/AIDS outside of the United States constituted a national security issue for the US, he might just as well have included tuberculosis in his declaration.

Years of empirical research have demonstrated that in many developed countries, including the United States, the major driver of TB incidence, including its resistant forms, is the in-migration of populations from areas where TB is endemic – mostly developing countries. These areas include slums, and, in fact, it is possible that much of the TB burden in the US and other developed countries originates in slums, though there is not yet an adequate empirical research base to support an unequivocal conclusion. Logic, however, would strongly suggest this (Kain, Benoit, Winston, & MacKenzie, 2008). Consequently, a great need exists for well-designed epidemiologic, geographic, and demographic research on this specific topic, and this should be a high priority for public health research. This would not only inform theory and our empirical research base, but would have obvious implications for public health practice and protocols.

Although their morphology may vary geographically, wide consensus exists on the defining characteristics of slums as spatially concentrated areas of impoverished population lacking basic urban amenities and infrastructure. UN Habitat, for example, in a definitive report on slums, identifies slums as high population density areas lacking adequate access to safe potable water and sanitation facilities; absence of waste collection systems; poor housing structure and insecure housing tenure; and concentrated poverty and relative exclusion from broader social and political processes (United Nations Human Settlements Program, 2003). Such social conditions constitute social environmental complexes that promote both infectious and chronic diseases. Our focus here is on a disease that illustrates the false dichotomy inherent in this binary classification: a transmissible, infectious disease that is chronic, with a long latency period and a long clinical course.

Tuberculosis

TB is one of the oldest documented human diseases. Physical and biological anthropologists have described TB infection that resulted in characteristic pulmonary scars in Egyptian mummies dating from 3000 to 2400 BCE. Syndromes that sound remarkably like tuberculosis were described by Plato, Hippocrates, and others (Daniel, 2009). Today TB is highly prevalent in many parts of the world, in part because it bears a reciprocal relationship with HIV/AIDS. Those with HIV/AIDS are much more likely to have active TB, and, in fact, TB is an 'AIDS defining' condition. This means that an HIV positive individual with active TB, by definition, has developed AIDS. In addition, those with active TB are much more likely to contract HIV. There is pronounced geographic overlap between areas that are high in AIDS prevalence and TB prevalence (Figures 1 and 2). The two epidemics – HIV/AIDS and TB – have been termed 'syndemic.' For example, the estimated 5–10% lifetime conversion of latent TB to active TB disease changes to a 10% *annual* risk of conversion if a child is HIV positive (Jaganath et al., 2013). According to the most recent World Health Organization (WHO) annual report on TB, estimates of causes of death globally indicate that if one considers only death due to infection, TB is second only to HIV/AIDS, depending on how infections are grouped. Aggregating all diarrheal diseases together, and similarly grouping together all lower respiratory infections – a frequent practice at WHO – alters these rankings somewhat. Because of differential reporting, exact data on TB mortality are impossible to derive directly, but the 2012 annual WHO report on TB estimated that approximately 1.3 million deaths were due to TB.

TB is caused by various strains of airborne mycobacteria, but for practical purposes we may limit these to one species: *Mycobacterium tuberculosis* (*M. tuberculosis* or,

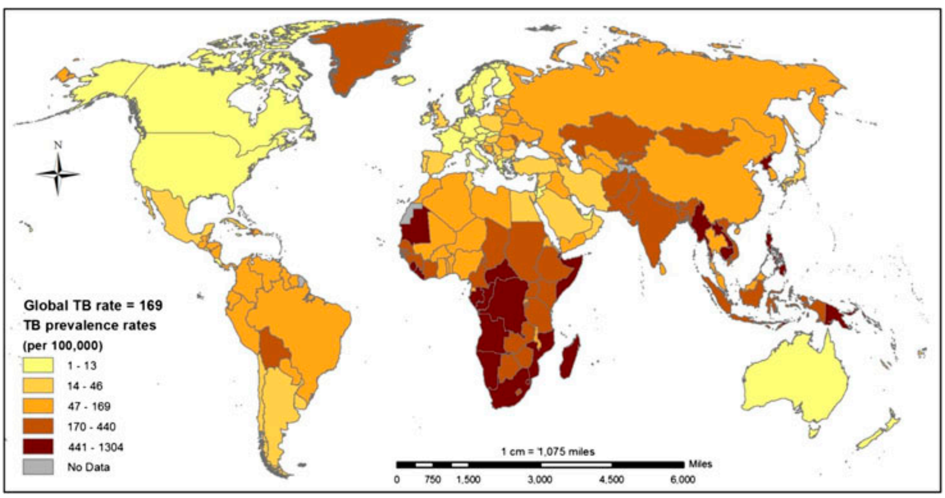

Figure 1. Spatial distribution of TB prevalence rates, 2012 (WHO, 2013).

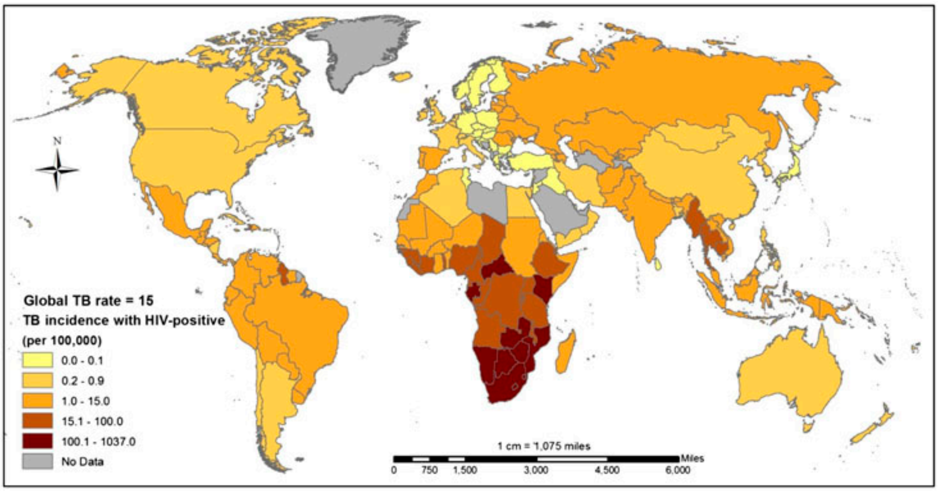

Figure 2. Spatial distribution of TB incidence of HIV positive, 2012 (WHO, 2013).

commonly, MTB). After inhalation, the bacteria settle deep within the pulmonary tree most typically, and frequently activate an immune process that ultimately results in granulomatous, walled off areas in the lung ('tuberculomas') within which bacteria reside, and are effectively contained. While MTB can infect multiple anatomic areas, pulmonary tuberculosis is, by far, the most common. Up to 90% of the population in developing countries may be infected by MTB, but multiple studies indicate that only 5–10% of the infections convert to disease at some point. For reasons that are poorly understood, MTB can begin to reproduce in the pulmonary tree in this small percentage, and the host can become symptomatic with cough, fever, night sweats, and weight loss. The pathogen can then be expelled from the body, and the host becomes contagious. Small genetic variants can affect transmission dynamics, and recently developed molecular techniques such as genotyping are useful in detecting these small variations. For example, minute variations in the genome that infects people, if identical, indicates that both people were involved in very recent transmission. Genotyping is also the best way to ascertain whether a person has been re-infected with a different strain of TB, or has relapsed, indicating treatment failure. Studying the genetic code of the mycobacteria enables us to better track and identify outbreaks, and combat drug resistance (Gafirita, Umubyeyi, & Asiimwe, 2012).

Poverty, malnutrition, and overcrowding are traditionally considered the primary risk factors for TB and, perhaps, causal factors. Engels observed the association of crowding, malnutrition, poor air quality, and poverty in the mid-nineteenth century (Engels, 1958). Malnutrition compromises the robustness of the immune system, so latent infection is more likely to become active TB in the malnourished. Overcrowding increases the frequency and intensity of interpersonal contact, and amplifies the risk of contagion of droplet or airborne infection. In most societies, there is an obvious association of poverty and population density. Of less relevance to TB, but crucial to the transmission of enteric diseases, is the association of poverty with inadequate sanitation and potable water. Poverty is also one of the many barriers to health care, thereby compromising the treatment of active TB. Significantly, health care is particularly absent in slum areas. As expected, TB is common in urban slums (David, Mercado, Becker, Edmundo, & Mugisha, 2007), and resistant strains are also common – perhaps increasingly so (Githui et al., 2004).

Over the past 50 years our understanding of TB has become more sophisticated. This includes the social and historical dimensions, as well as the molecular epidemiology, pathophysiology, and treatment of the disease. The presence of HIV/AIDS, which appears to have not been present at all in urban areas in Africa until the 1980s (though there have been recent isolated descriptions of HIV in what was then Leopoldville, Congo, in the 1960s), has complicated the situation immensely. HIV/AIDS suppresses the body's immune system and allows tuberculosis to progress to active status. Other health conditions such as diabetes or advanced age that compromise the body's defenses also contribute to TB risk (Millet et al., 2011). Old age and the presence of diabetes are both associated with less robust immune response. Finally, inappropriate treatment produces drug-resistant strains of TB on both the individual and community levels (Gafirita et al., 2012). Resistance to single and multiple medications is, unfortunately, common, and extensively resistant strains are becoming more common. Moreover, if there is no testing for drug sensitivity, which is the norm in impoverished areas, by the time that treatment failure is identified, the harm has already been done.

Estimates of the case fatality ratio of untreated pulmonary TB vary, but range from approximately 50% to nearly 90%, with a median of approximately 70% over a 10-year period (Tiemersma, van der Werf, Borgdorff, Williams, & Nagelkerke, 2011). With appropriate treatment and early detection of active disease in HIV-negative patients, the case fatality ratio can drop to less than 1% (Millet et al., 2011). This figure depends on the stage of the disease, co-morbidities of the patient, and the availability of appropriate testing facilities and medication.

Resistant strains of TB make treatment far more complex. Ironically, the existence of resistant strains is itself the product of inadequate treatment, lack of funds to ascertain drug sensitivities in deprived areas, and insufficient patient adherence. Multi-drug-resistant TB (MDR-TB) is caused by mycobacteria that do not respond therapeutically to isoniazid or rifampin (rifampicin in some countries), which are the two first-line treatments. Extensively drug-resistant TB (XDR-TB) does not respond to any of the first line of TB drugs or at least one injectable second-line treatment plus one of the other second-line medications, one of the respiratory fluoroquinolones (Saleem & Azher, 2013). The incidence and prevalence rates of MDR-TB and XDR-TB are impossible to know with precision because of differences in reporting, but the most recent WHO estimates are that globally about 3.4% of all new TB cases are MDR-TB or XDR-TB, and approximately 20% of cases that have already been treated are resistant (WHO, 2013). That same report noted, unfortunately, that 75% of resistant cases go undetected. Interestingly, whether or not a patient has been treated for TB in the past is one of the most reliable predictors of resistance: those who have been treated previously are more likely to be infected by resistant organisms. Moreover, the prevalence rate of resistance appears to be increasing. In other words, globally, the problem appears to be uncontrolled and in urban slums the extent and severity remain largely unknown.

Ascertaining whether TB cases are resistant can be difficult. It requires performing cultures and sensitivities, and this is rarely done in developing countries. In fact, in poorer areas, individual drug resistance testing is not done until patients fail an initial course of treatment – that is, after many months with inappropriate medication have elapsed. This intensifies the problem of resistance since it selects for resistant strains, and compromises individual- and population-level outcomes (Mak et al., 2008).

Non-compliant patients are most likely responsible for the development of MDR-TB and XDR-TB by introducing the organism to the drug but not finishing the cycle. Worse still, only one in ten people with active drug-resistant infections have access to appropriate care (Millet et al., 2011). Many of these chronic cases of TB live in the community infecting others because of non-existent quarantine protocol.

Traveling diseases

Globalization is transforming disease transmission patterns. Technological advancements shrink time and space, encouraging increased cultural and economic interdependence. Immigrants have always provided a vital link in disease transmission between their home regions and their destination; however, modern technology enables nearly instant travel-related disease spread. National boundaries no longer offer isolation or protection. Permanent migrants are not the only means of disease spread; short-term visitors, including tourists, are also important in the spatial diffusion of microbes and pathogens. Though TB transmission on airplanes has been documented, it appears not to be common (Kenyon, Valway, Ihle, Onorato, & Castro, 1996). Nonetheless, there is some risk of transmission of TB on airplanes, constituting a small risk while actually traveling, as suggested by mathematical models (Gwangpyo, Thompson, & Nardell, 2004). In many cases, however, those with active TB face quarantine or difficulty obtaining visas, and official recommendations are that (1) air travel for those with active TB should be prohibited; (2) contact tracing must occur after suspected contact; and (3) commercial air travel should not be allowed for those with active TB (Abubakar, 2010) (Figures 3 and 4).

In developed countries, newly diagnosed TB occurs most frequently among foreign-born immigrants. For example, in France immigrants are six times more likely to be diagnosed with TB than the native born (Carballo & Nerurkar, 2001). In Canada, while representing only 18% of the total population the foreign born accounted for 62% of all reported TB cases in 2008 (Public Health Agency of Canada, 2012). In the United States, the TB rate among foreign-born persons was 11 times greater than among US-born individuals (Centers for Disease Control and Prevention, 2011). Consequently, states or provinces with a greater percentage of immigrant populations tend to have

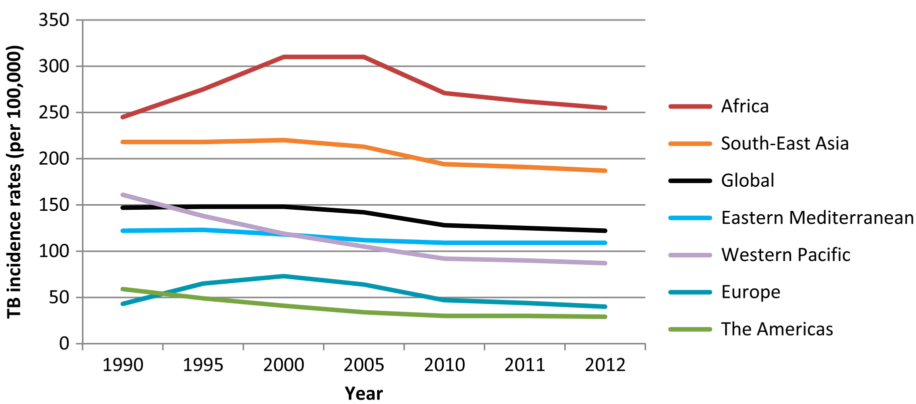

Figure 3. Estimated TB incidence rates by WHO region from 1990 to 2012 (WHO, 2013).

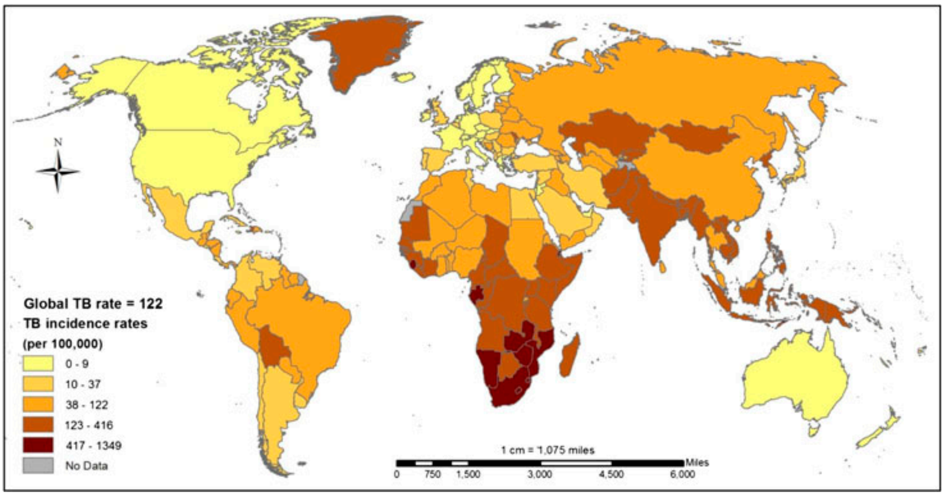

Figure 4. Spatial distribution of TB incidence rates, 2012 (WHO, 2013).

higher TB rates than other states or provinces, depending on the origins of the immigrants. The populations of British Columbia, Ontario, and Quebec, which represent the provinces with the largest number of migrants in Canada, accounted for 87% of foreign-born tuberculosis cases in 2003 (Public Health Agency of Canada, 2003). Moreover, a disproportionate number of cases were reported from large cities with major concentrations of foreign and ethnic minorities such as Toronto, Montreal, and Vancouver. Similarly, five states in the US – California, New York, Florida, Texas, and Illinois – accounted for nearly half (49.2%) of all TB cases in 2010 (Centers for Disease Control and Prevention, 2011) and the 48 largest cities accounted for 36% of all US patients with TB (Oren, Winston, Pratt, Robinson, & Narita, 2011). As in Canada, major US cities, including New York, Los Angeles, San Francisco, San Diego, Miami, Atlanta, and Houston, all report disproportionately high numbers of cases in neighborhoods consisting of large percentages of foreign born.

A crowded world

More than half of the world's population currently lives in urban areas. Current predictions from the UN, and a large number of demographers, predict that by 2030 this will increase to 66% and to almost 75% by the middle of the century. Most of the predicted global population growth (over two billion people in the next 30 years) is expected to occur in urban areas in the developing world (Cohen, 2006). The rapidity of urban growth overwhelms existing and projected local service capacities for potable water, sanitation, transportation, and other services. Despite this, cities in developing countries continue to attract internal migrants in search of employment, exacerbating the problems of urban congestion, sprawl, water shortages, and air and water pollution. The latter are major contributors to cardiorespiratory diseases. The poorest migrants with the least access to strained resources often reside in informal settlements or slums.

Seventy-eight percent of the urban population in the least developed countries live in slums (United Nations Human Settlements Program, 2003). Despite the dire conditions of the majority of urban residents the issue of slums lacks as much visibility in policy circles as does rural poverty. There is a rural bias to both private and public donations. A news item three years ago in *The Lancet* summarized some of the attention that is now being given to urban areas in poor countries. Though concentrating more on Asian slums than African slums, the author concludes that: 'Developing nations and foreign donors have ignored the problem to an extraordinary degree… [donors] have continued to focus on the rural poor,' (Shetty, 2011) largely because these areas are easier to serve – particularly with vertical programs.

The poor infrastructure of slums exacerbates the risk of disease spread. Lack of potable water produces high rates of diarrheal diseases due to multiple pathogens. One example is the cholera epidemic in Africa in 2012, where there was disproportionate morbidity and mortality in coastal slums (Nossiter, 2012). Urban water distribution systems in the developing world typically serve the upper class and middle-class neighborhoods but not the rapidly expanding squatter settlements and slums (United Nations Human Settlements Program, 2005). Service to upper class and middle-class neighborhoods is also often inadequate. Frequently, the scarcity of potable public water leaves little choice in many poor areas other than to use private water vendors who charge many times more than the local public rate. In a house-to-house survey conducted by two of the authors in Nima, Ghana (JM and JO), estimates were that 40% of the household budget was spent on acquiring water – a figure that is perfectly in line with that of other slum communities (Satterthwaite, 1997). Consequently, the poor pay more for water than the wealthy. Poor access to sanitation such as sewers and private toilets perpetuates numerous diarrheal and gastrointestinal diseases. Nutrition is often inadequate, resulting in wasting and starvation, which increases susceptibility to infection and compromise the neurologic and intellectual development of the young.

Slums are the result of both broad global forces and local factors. Urban policy in developing countries promotes the growth and isolation of slums. Consequently, slums are one instance of 'structural violence,' an arrangement of social institutions in a manner that prevents the realization of human potential, including freedom of choice, high quality of life, and basic survival (Farmer, Nizeye, Stulac, & Keshavjee, 2006). Neglected by government, donor agencies, and urban planners, slums rarely receive official acknowledgment since they often exist illegally as squatter settlements. Census coverage is spotty, health surveys nearly non-existent, and maps are rare.

African slums

African slums are particularly important in developing an understanding of the more general phenomenon of slums in developing countries. In an analysis of the political economy of slums, Fox argues that the acuity of social problems, and their extent, is particularly great in Africa:

> The challenge of slums is particularly acute in sub-Saharan Africa. Although the region contains just 13% of the urban population of developing regions, it hosts 25% of the slum population of developing regions …. Over 60% of sub-Saharan Africa's urban population lives in slum conditions; the highest level of 'slum incidence' of any major world region and significantly higher than the developing region average of 32.7%. (Fox, 2014)

African urban slum dwellers bear a disproportionate weight of global poverty. The per capita income in many African countries is lower now than it was at the end of the 1960s

(World Bank, 2002), and nearly half (48.5%) of the population of sub-Saharan Africa lived on $1.25 or less a day in 2012. In 1980, only 10% of the global poor lived in sub-Saharan Africa; in 2000, it was over 30%. Africa has the highest incidence of slums in the world; nearly two-thirds of urban African lives in slums. Trends suggest that future urban growth in Africa will take place mostly in slums and informal settlements (United Nations Human Settlements Program, 2003). The collective influence of extreme poverty, high population density, illiteracy, and HIV/AIDS provides an ideal environment for TB spread.

There is a dearth of empirical research that examines health conditions in slums in developing countries. A disproportionate amount is from Nairobi, Kenya, the home of several of the largest and best-studied slums. This, in part, is because of the presence of the African Population Health and Research Centre – perhaps the largest think-tank on urban health in developing countries. Indeed, one of the additional challenges in understanding slum health is that there are seldom accurate official data on basic demographic issues, including total population – much less on birth and death rates. Additional challenges include violence, exposure to air pollution, road traffic injuries, and a whole range of infectious diseases such as HIV/AIDS, influenza, and childhood illnesses such as measles. Vaccine uptake rates are uncertain and accessibility to vaccine is limited. As increasing number of people live in urban areas and adopt urban lifestyles, any combinations of unhealthy diet, physical inactivity, and misuse of alcohol, tobacco, or drugs are also likely to increase the incidence of chronic diseases as well as infections like TB.

Although our understanding of African urban slum health conditions is severely lacking, the limited evidence is disturbing. The World Health Organization's Commission on Social Determinants of Health summarized most of the major causes of morbidity and mortality in slums, and compared the prevalence of these causes within and outside slums. The high prevalence of all identified health conditions was vastly worse in slums compared to other areas (WHO, 2008). In Mathare, a slum in Nairobi, the under-5 mortality rate is four times that of Kenya as a whole (Kyobutungi, Ziraba, Ezeh, & Ye, 2008). Overcrowding and poor ventilation make this an apt setting for the spread of communicable respiratory diseases including MDR-TB (Clarke, 2007). Such conditions in urban slums have created 'disease magnets' – areas that not only attract infectious diseases, but also serve as incubators of infection (Garrett, 1994).

In terms of TB incidence rate, 13 of the world's top 15 countries are in sub-Saharan Africa (Figure 4). The TB incidence rate in Africa in 2012 was estimated by WHO to be 360/100,000 (WHO, 2013). In Khayelitsha, a slum situated 30 km from Cape Town, South Africa, around 4.4% of TB notifications are for multi-drug-resistant strains (Cox et al., 2010).

A closer look at West Africa

The burden of TB is not evenly distributed across the continent. The burden is highest in countries with very high rates of HIV infection. In Swaziland, where one in three adults has HIV, the TB rate is 1349/100,000 while Kenya's TB rate is only 272/100,000 (Figure 5). The lowest TB rates in sub-Saharan Africa can be found in West Africa; the rate in Ghana was 72/100,000, only 5% of the rate in Swaziland. Studies on TB in slums or cities have focused on Uganda, Kenya, Rwanda, and Malawi. However, it would be a mistake to ignore West Africa.

West Africa, especially Ghana, is plugged into the global community. On a typical Wednesday, flights arrive at Kotoka International Airport in Accra from Rome, New York, Amsterdam, Frankfort, Lisbon, and London. In the US, migrants from West

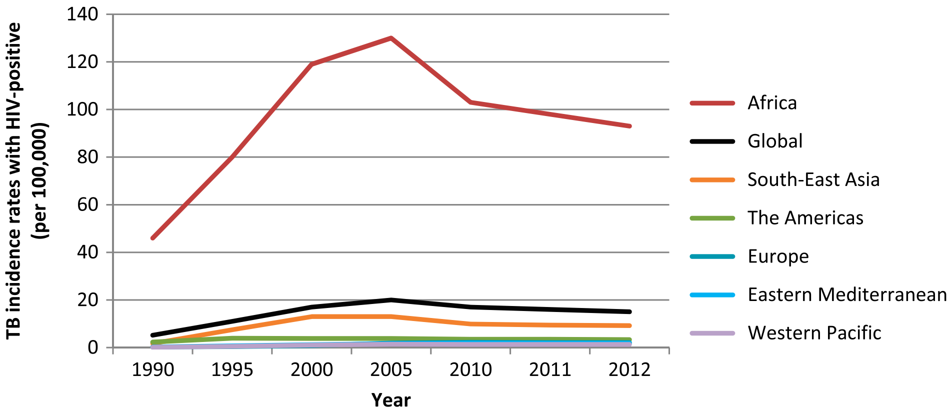

Figure 5. Estimated TB incidence rates of HIV positive by WHO region from 1990 to 2012 (WHO, 2013).

Africa are the largest group from sub-Saharan Africa. Over half a million people (573,711) migrated from West Africa between 2008 and 2012. From Ghana alone 120,785 people moved to the US, more than that from the entire high TB-burdened Southern region (86,323). Despite reason to suspect that MDR-TB may be more common among Ghanaian TB patients, MDR-TB testing is not available to new TB patients, and to only 5% of retreatment cases (WHO, 2013). Worse yet, 42% of urban Ghanaians live in slums. Nima-Maamobi is one such slum in Accra, located less than three miles from the Kotoka International Airport.

Slum health in West Africa: the example of Nima-Maamobi

Nima (more properly, Nima-Maamobi) is a slum of mixed ethnicity close to the center of Accra, Ghana. The population is approximately 150,000 on 6 km^2. While most structures are permanent, living conditions and sanitation are poor by any standard, and population densities are high, with one of the lowest housing quality indices in Accra (Weeks et al., 2012). Approximately 30% of census respondents are Christian, and 60% are Muslim, mostly migrants or their descendants from predominantly Muslim northern Ghana or Muslim portions of other nearby countries. New migrants are attracted by religion, family ties, and economic opportunity (Owusu, Agyei-Mensah, & Lund, 2008). Sewers are usually open and most residents obtain potable water through private, commercial sources, or by tapping into pipes that do not enter the household. A Slum Vulnerability Index, similar to previous indices (Jankowska, Weeks, & Engstrom, 2012), incorporating sanitation, housing, overcrowding, water access, and tenure insecurity across 11 enumeration areas (EA) in Nima has confirmed that vulnerability is both high and quite variable across the slum (Aggrey-Korsah & Oppong, 2013). 'Hot spots' of malaria and non-communicable diseases in particular were found in various EAs. Beyond that, very little is known of the health or demographic conditions of Nima, since no systematic health surveys of the area exist. The prevalence of TB is unknown since TB is discovered only when people go to the clinic for testing and treatment, which is usually when they are symptomatic. This is typical of African slums such as Kibera, Nairobi (Kizito, Dunkley, Kingori, & Reid, 2011).

The challenge of TB control in Nima is formidable. Only two clinics, with a total of three full-time physicians, serve a population of between 110,000 and 150,000. Passive surveillance, the norm, is inadequate as a means of detecting most TB cases, and untreated TB poses a serious public health problem. Moreover, the treatment regimens that are followed in Nima and other African urban slums support the survival of resistant strains because it is only when first-line treatment fails twice that sputum is collected for culture and sensitivity. By the time MDR-TB or XDR-TB is discovered, usually at least 6 months after infection, the drug-resistant strain has probably been passed to others. Thus, population conditions are ideal for TB transmission. High rates of HIV and inappropriate treatment strategies keep the epidemic going while surveillance strategies catch only a small percentage of active TB cases. As a result, early detection and adequate treatment are crucial to interrupt the chains of transmission. However, this is impossible, given the existing testing and treatment protocols.

A research agenda for TB in African urban slums

In the US, screening and treatment targeting high-risk populations is currently the main strategy for TB control (Centers for Disease Control and Prevention, 2008). Moonan et al. (2004) identified geographical areas with ongoing tuberculosis transmission by linking geographic information systems (GIS) technology with molecular surveillance. The study concluded that this approach provides an effective method for identifying and interrupting instances of local transmission (Moonan et al., 2004), and ultimately reduces incidence. Subsequently, the same team (Moonan et al., 2006) reported location-based TB screenings implemented in partnership with multiple community-based organizations. Local public health officials, using information from TB strain genotyping and GIS analysis, were able to develop and initiate a highly successful tuberculosis control intervention (Reves, 2006). To our knowledge, such location-based targeted screening and control of TB has not been implemented in Africa.

In most African countries, and certainly throughout Ghana, passive surveillance using clinic visits and occasional contact tracing are the main methods of TB control. Yet passive surveillance depends entirely upon those with TB actually present at clinics, a rare event in poor areas. Undetected and untreated TB leads to spreading, but as demonstrated in South Africa active surveillance finds TB cases earlier and thereby can reduce transmission (Den Boon et al., 2008). The Karonga Prevention Study in northern Malawi established that in an even poorer sub-Saharan African environment, genotyping can establish essential parameters of infection, including resistance patterns (Glynn et al., 2008), and patients can quickly start appropriate medications, thereby decreasing the time to cure and the number of people who are exposed to this person carrying resistant organisms. What is needed in Africa's urban slums is an aggressive deployment of a research effort that combines the strength of contact tracing with spatial targeting. Targeting confirmed TB cases and their social and neighborhood networks for increased screening and treatment is probably a viable strategy. Thinking more upstream, it is critical to reduce the vulnerability of people's living conditions (Jorgensen, 2008) so that the environment is less favorable to TB transmission.

Conclusion

Clearly, urbanization is having a major impact on the state of public health in the twenty-first century. The reality is stark: rapid urbanization poses serious global health challenges (Sharma, 2010). Nowhere is the problem more troubling than in the squalid, overcrowded mega-slums of poor developing countries. Potentially, they constitute unprecedented incubators of new and re-emergent diseases that can travel across the world at the speed of a passenger jet.

In Africa today, extreme rural poverty is pushing residents out in droves. New arrivals to Africa's urban areas confront the extreme margin of human marginal existence. In a desperate move of sheer survival, they turn to the already overcrowded slums, exacerbating the concentration of disadvantage. And because the geographic location of slums is becoming more and more marginal, the destructive power of natural elements such as flooding and storms leaves today's slum residents in an ever more vulnerable state.

Continued neglect of slum health in developing countries is a perfect recipe for disaster. Next time, it may be a global pandemic of a multi-drug-resistant communicable disease that has emerged out of the slums of Africa.

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