The Journal of Infectious Diseases
SUPPLEMENT ARTICLE

Rise of Informal Slums and the Next Global Pandemic

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Informal slums are growing exponentially in the developing world and these will serve as the breeding ground for a future global pandemic. Virtually every sustainable development goal is unmet in slums around the globe thus we must act now to divert a global humanitarian crisis.

Keywords. health; infectious diseases; informal slum; pandemic; slum; urban; WASH.

RISE OF INFORMAL SLUMS

The world's population is growing exponentially and is not expected to plateau until the 22nd century. Most of this growth is taking place in urban slums of low- and middle-income countries (LMICs) [1, 2]. Presently, there are over 1 billion people living in slums and this is expected to rise to 3 billion by 2050 [1]. The largest slums in the world are situated in Africa (Khayelitsha, Cape Town; Kibera, Nairobi), India (Dharavi, Mumbai), Pakistan (Orangi Town, Karachi), Bangladesh (Korail, Dhaka), and Mexico (Neza, Mexico City) (Figure 1). Slums can be classified as formal, where the land on which the residents reside is recognized by the government, or informal, where the land is unrecognized. In the developing world, informal slums predominate, growing horizontally around large overcrowded urban centers [1, 2].

PANDEMIC THREATS

The global history of emerging or reemerging infectious diseases shows that, on average, they have appeared about once a decade since 1940 [4, 5]. Recently, however, the time between pandemics has become shorter, as evident from severe acute respiratory syndrome (SARS-CoV-1) in 2003, influenza A H5N1 (bird flu) in 2007, H1N1 (swine flu) in 2009, Middle East respiratory syndrome (MERS) in 2012, Ebola virus in 2014, and SARS-CoV-2 in 2019 [4–6]. Overpopulation and poverty are the primary contributing factors that have brought about this change and are strongly linked with global warming, environmental degradation, habitat destruction, and increased human-host-reservoir interaction [4–6]. In metropolitan Manila and Dhaka, approximately 12 million people live in slums with no piped water or toilets [5, 6]. According to the World Health Organization (WHO), 137 million people in urban centers have no access to safe drinking water and over 600 million lack sanitation [5, 6]. Moreover, population density is directly correlated with the rate of transmission of respiratory and fecal-oral pathogens (eg, *Mycobacterium tuberculosis*, influenza, cholera, rotavirus, and helminths) [5, 6].

Multidrug resistance (MDR) in *Mycobacterium tuberculosis*, *Streptococcus pneumoniae*, and *Staphylococcus aureus* are a global concern and gram-negative bacteria resistance to β-lactams is widespread [5, 7]. Drug resistance in enteropathogens has also become a major global health challenge. MDR *Salmonella enterica* Typhi and *S. enterica* Paratyphi are common in Asia and sub-Saharan Africa, and there are increasing reports of reduced susceptibility to fluoroquinolones [5, 8]. *Campylobacter jejuni* resistance to fluoroquinolones has become a concern in Southeast Asia, with rates of resistance of 80% reported from Thailand [5, 8]. Viral pathogens (eg, Ebola Makona variant (EBOV), MERS-CoV, H1N1, and SARS-CoV-2) are also of concern due to their high rates of nucleotide substitution, poor mutation error correction rate ability, and capacity to quickly adapt to human hosts [5, 9].

DOUBLE BURDEN OF DISEASE

Residents of informal slums face a double burden of disease. Those who survive the infectious disease (eg, Rotavirus, *Cryptosporidium, Shigella*, *Campylobacter*, *Salmonella* Typhi, and *Vibrio cholerae*) onslaught of childhood face the burden of chronic diseases (eg, tuberculosis, diabetes, cardiovascular disease, and stroke) in adulthood [1, 2, 10]. The drinking water in slums, even if piped, is contaminated with multiple enteropathogens [1]. Infants as young as 12 weeks of age are

Presented in part: Asian Conference on Diarrhoeal Disease and Nutrition in Dhaka, Bangladesh, 2020.

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The Journal of Infectious Diseases® 2021;224(S7):S910–4

https://doi.org/10.1093/infdis/jiab492

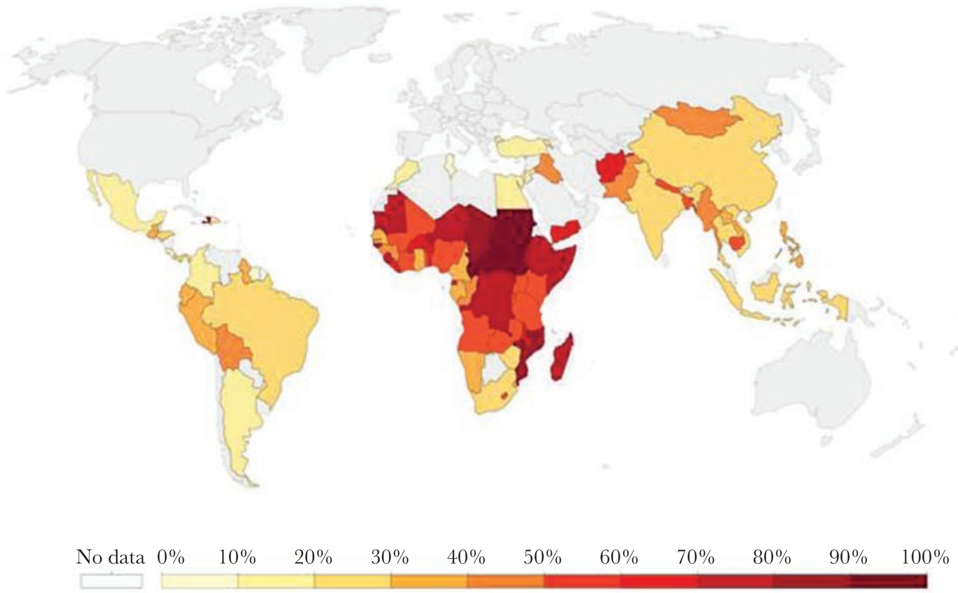

Figure 1. 1998 global distribution (%) of urban slum populations. Adapted from UN Habitat: https://ourworldindata.org/grapher/share-of-urban-population-living-in-slums [3].

often infected with 1 or more pathogens [1]. Enteric pathogens present in the intestinal tract of young children can cause intestinal inflammation and frequent diarrhea, disrupting intake of nutrients (malnutrition), which results in impaired growth (stunting) and poor cognitive development [11]. An estimated 250 million young children in LMICs are locked in this vicious cycle and they never achieve their developmental potential [12, 13]. Residents know that they are at risk of infection if they drink the well or tap water but have little choice given it is too expensive to boil, and chlorinated water is less palatable [1]. Hygiene and health education are poor, thus fecal-oral pathogens flourish year-round.

WASH

In informal slums, water, sanitation, and hygiene (WASH) infrastructure is primitive or nonexistent given the land is not recognized by the government (Figure 2) [1]. Moreover, the land is typically flood prone, thus it is not suitable for formal sewage or

Figure 2. Informal slum conditions in Dhaka, Bangladesh: (A) unsafe drinking water; (B) overcrowding; (C) poor sanitation and hygiene; (D) inappropriate waste management.

water lines (ie, there is excess pressure on the pipes during the flood season) [1]. During the monsoon season, raw sewage enters the home and often contaminates the drinking water [1]. Cheap WASH interventions have largely failed and most governments are unwilling to invest in formal sewage systems and waste treatment plants in informal slums [14]. So, what can we offer residents to improve their quality of life? Two possible WASH interventions are a solar-powered water filter and an onsite anaerobic/aerobic biodegradation sewage system developed in India [1].

A solar-powered water filter developed by NB Institute of Rural Technology in Kolkata, India appears to be an attractive option for the contaminated piped water of informal slums and globally. If clean uncontaminated water can be provided via ultrafiltration at the compound level (ie, 10 households with approximately 50 residents) this would be a major step forward. Developed by one of the authors (S. C.), the device will not just be able to treat water of excess iron, suspended particles, and bacteria through filters and solar powered UV light, but can even save at least 30 units of Kilowatt-Hour power in a month. The purifier comes in 2 sizes. While the smaller domestic version has a capacity for around 50 liters and costs around US$188, the larger one could be installed in public places and has a capacity of 300–400 liters and is priced at US$536. Unlike the traditional purifiers, these can store water, which could be used at night and on cloudy days when the water purifier is not working. The filters need to be changed only once per year.

Aquatherm (https://aquathermindia.org), also based in Kolkata, India, has proposed a toilet with the provision for waste treatment (Hiclear system) through the use of an onsite anaerobic/aerobic biodegradation system. This is a unique process where the biological activity is maintained for over 25 years with the help of a range of bacteria. The aerobic bacteria act in the upper zone and the anaerobic bacteria in the lower zone. The intermediate zone thrives with transitional or facilitative bacteria. This above-ground system has been modified for flood-prone urban slums and is ready to be deployed at compounds. The sewage system is fully automatic, the treated water characteristics are unmatched by any other sewage treatment plant without resorting to tertiary treatment, and the treatment unit can be moved to a new location if required, which is not possible for other modes of treatment. Moreover, the treatment unit does not require a water line to be connected. The treated water produced by the system can be safely used in gardening, aquaculture, or hydroponics. The Hiclear systems are presently used by the United Nations for their Peace Keeping Force camps and have been installed in various countries around the world including India, the Maldives, Thailand, Singapore, Australia, and Oman.

HEALTH INTERVENTIONS

What low-cost health interventions should be provided in informal slums? The Expanded Program on Immunization (EPI), plus rotavirus, typhoid, cholera, and enterotoxigenic *Escherichia coli* vaccination would appear to be appropriate and cost-effective based on recent clinical trials [15–17]. Cholera remains a serious global health problem despite advances in the understanding of its pathogenesis and treatment. A single dose of the oral cholera vaccine (OCV), Shanchol, was recently proven to be efficacious in older children (≥5 years of age) and in adults in a setting with a high level of cholera endemicity (eg, Dhaka slums) and is currently WHO prequalified [15, 16]. A recent OCV trial (ie, 2 doses of the bivalent whole-cell inactivated vaccine Shanchol) demonstrated a total vaccine protective effectiveness of 53% against severely dehydrating cholera 2 years after vaccination but the vaccine efficacy was only 16% for children younger than 5 years [15]. However, when OCV was combined with "cheap WASH" (ie, handwashing and treatment of drinking water with chlorine) as part of another trial arm the total vaccine protective effectiveness increased modestly from 53% to 58% [15]. In the Rohingya camps, we recently conducted the largest preemptive cholera vaccination campaign in history that has to date prevented an outbreak [18]. There are a number of nongovernmental organizations working within the camps providing a range of WASH solutions from cheap low-cost WHO drinking water solutions to the expensive Oxfam sanitation system [18]. The evidence to date suggests that OCV alone will not contain an outbreak of cholera, thus we believe the WASH interventions have worked synergistically with mass vaccination in halting an outbreak within the camps. Rotavirus is the leading cause of severe gastroenteritis in children younger than 5 years [19, 20]. In clinical trials, Rotarix was found to be efficacious against severe rotavirus gastroenteritis in infants up to 2 years of age in Europe (90.4%) and Latin America (80.5%), and up to 3 years of age in Asia (96.9%), with no safety concerns [19, 20]. The results of a rotavirus vaccine trial for infants conducted in urban Dhaka slums (ie, 2 doses of the oral vaccine Rotarix at 10 and 17 weeks of age) showed the vaccine to be far less efficacious (31%) than levels of efficacy seen in infants and young children in industrialized settings [12].

Health education stressing the importance of hand washing with soap has been shown to be effective in reducing the incidence of pneumonia and diarrhea in slums by 50% [21]. Annual mass drug administrative campaigns for neglected tropical diseases (eg, soil-transmitted helminths) have been heavily advocated by WHO and other international agencies. Given the high prevalence of parasitic worms in slums, annual deworming (eg, 400 mg albendazole) would appear to be economical. The treatment of chronic diseases (eg, metformin for diabetes, statins for hyperlipidemia, angiotensin-converting enzyme inhibitor [ACEi] and an angiotensin receptor blocker [ARB] for hypertension) is a more complicated matter, given that a diagnosis typically leads to life-long treatment. Metformin and antihypertensives are relatively cheap but statins are not. Slum children with severe acute malnutrition should receive micronutrient supplementation using a locally modified, ready-to-use therapeutic food (RUTF) with demonstrated immune-modulating functions, including iron, zinc, calcium, vitamins A, B, and C, and n-3 and n-6 fatty acids [22, 23]. An average full course of treatment for a child amounts to approximately 10–15 kg of RUTF over an 8-week period [22, 23]. Reproductive health strategies, comprising female health education in the home and pills/condoms/Depo-Provera, distributed at government-run slum health dispensaries, are imperative for meeting the reproductive health needs of these underserved populations.

The above evidence-based health package is relatively cheap but there are many challenges in rolling it out in LMICs. Most healthcare personnel do not want to work in slums (eg, due to unhygienic conditions, safety concerns, etc.) thus treatment and vaccination rates are typically low (<25% coverage) [17]. The annual in/out migration in urban slums is high (approximately 10%–25%), which impacts sustainability [1]. Providing herd immunity is an enormous challenge in slums, thus the greater urban population is at risk for future epidemics. The level of education attainment among slum dwellers is very low (eg, primary level), thus health education campaigns are difficult and behavioral change is often short lived (<6 months). The cost of chronic disease medications must be heavily subsidized by the government. To date, most countries appear unwilling to provide such benefits for the poorest sector of their society.

TOWARDS 2050

To avert a humanitarian crisis in slums, we must provide an evidence-based WASH and health intervention package that is affordable for informal slum dwellers. National governments appear unwilling to provide such services in informal slums. So, how will slum residents be able to afford such a package? The proposed WASH component (eg, solar-powered water purifier, water storage tank, onsite sewage treatment system, and 4 toilets) at the compound level would cost approximately US$5000 for the equipment and installation. The health interventions are cheap (approximately US$500 per annum) and could be partially subsidized by the government (eg, EPI vaccination). A slum cooperative or microfinancing at the compound level may be the way forward. Ultimately, slum dwellers must take ownership of their own destiny if they are to improve their quality of life. This appears to be the only sustainable path forward. If we fail to act, overcrowded informal slums with no formal sewage systems, contaminated drinking water, and high burden of drug resistance pathogens could serve as the breeding ground for the next global pandemic.

Notes

Acknowledgments. We thank our core donors from Canada, Sweden the United Kingdom and Bangladesh for their generous support.

Potential conflicts of interest. All authors: No reported conflicts of interest. All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed.

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