Introduction

One of the biggest challenges facing humanity is the achievement of water security, i.e., ensuring sustainable access to a safe, affordable, reliable, and accessible supply of drinking water for all. Over the past three decades there has been significant progress: 2.6 billion people gained access to improved drinking water between 1990 and 2015, and 147 countries met their Millennium Development Goal (MDG) target to reduce by half the population without access to an improved water source (WHO and UNICEF 2015). Despite this progress, approximately 663 million people worldwide still lack access to improved drinking water sources, with substantial regional variation in coverage, and urban–rural disparities (WHO and UNICEF 2015). Even though 96% of global urban dwellers now use improved sources, the brunt of urban water insecurity falls disproportionately on residents of urban slums, defined by the United Nations (UN) as “urban areas without basic services such as safe water, sanitation, electricity etc., and characterized by poor housing, overcrowding, insecure tenure, and social exclusion” (UN Habitat 2013; UNSD 2015).

One of the biggest challenges to addressing water insecurity in urban slums is that global water access targets, monitoring, and policy platforms have struggled to clearly quantify the scope of the problem. Monitoring statistics have been criticized for being overly simplistic and relying on averages which mask stark intra-country disparities (Clasen 2012; Smiley 2017). Governmental leaders and policy makers have often turned a blind eye to slum communities, whether owing to the perception of the slum as urban blight or owing to the perceived illegitimacy of a settlement. Much of this is tied to the historical stigma associated with the term “slum” itself (Gilbert 2007). (We use “slum” in the same way as do many major development agencies, journals, and researchers (e.g., Ezeh et al. 2017; Lilford et al. 2017; UN Habitat 2013), which generally denotes limited infrastructure and governance. Popular alternative terms such as “informal settlements” or “low-income communities” are no better at capturing the nature of human activity in these neighborhoods, much of which is quite formal and not limited to low-income residents. The institutional perception of slum communities has often limited the collection of baseline data on slum population demographics, economic activity, and gaps in basic service delivery. Urban water access statistics, in particular, may not explicitly consider slums, and the corresponding MDG encapsulated all drinking water concerns into one goal: to decrease by half the number of people across the globe without access to safe water. The more recent Sustainable Development Goals (SDGs), while ambitiously specifying under Goal 6 the need to “ensure universal access to safe and affordable drinking water for all by 2030,” do not explicitly capture the scale of water insecurity in urban slums as a potential target area. The UN has,
however, highlighted the need for “quality, accessible, timely and reliable disaggregated data” to monitor progress towards the SDGs (UN 2015).

Water security implies sustainable access to an appropriate quantity and quality of affordable water within the broader context of developing human capabilities, and ensuring socio-political justice and cultural acceptability (Jepson et al. 2017). The UN and World Health Organization (WHO) acknowledge widening disparities in water security around the world, and that major gains in access to water have often benefited only the wealthy and more socio-economically advantaged (WHO and UNICEF 2015). In urban areas, where water access may appear more comprehensive than in rural areas, growing populations of slum residents—who are often poor, vulnerable, and marginalized—usually have disproportionately worse access to formal water supplies (i.e. piped water) compared with other urban residents. Even though access rates are still relatively lower in rural areas, much less progress has been made on urban water provision in recent years. Marginal improvements to urban water supplies have been outstripped by demand from persistent, unplanned population growth that is driven by rural-to-urban migration. Urban areas commonly exhibit spatial disparities in access, where some areas are better endowed with improved water sources than other areas that receive less investment. At the national and sub-national levels, political will to prioritize slums for infrastructure projects has been weak and has historically been plagued by inadequate financial investment. These trends continue today and raise important questions about how water security can be bolstered in urban slums as the gap between urban water supply and demand continues to widen.

The health implications of poor access to water are profound. A plethora of studies have consistently noted drinking water as an important pathway for human exposure to environmental hazards (Bartram and Cairncross 2010; Fewtrell 2004). Over the past few decades, the linkage between water quality and health has gained increased attention as more empirical evidence demonstrates that a substantial number of mortality cases in developing countries are attributable to poor access to drinking water and sanitation (Fink et al. 2011). Prüss-Ustün et al. (2008) estimated that as much as 10% of the global disease burden and 4% of mortality can be prevented by effective interventions and improvements in drinking water and sanitation. While developing countries disproportionately bear a bigger fraction of the burden of morbidity and mortality from unsafe water and poor sanitation and hygiene, sub-Saharan Africa (SSA) ranks alongside South Asia as the region with the greatest disease burden from water-related conditions.

Scholarship on the general health of slum residents is a subject of growing interest in the broad context of development in middle- and low-income countries (Fink et al. 2014), and specifically sub-Saharan Africa (Oppong et al. 2015), with “slum health” recently recognized as an important sub-discipline of global urban health (Lilford et al. 2017). While past studies have explored various social dimensions of water security among Africa’s urban poor such as flood risk (Douglas et al. 2008), livelihoods and social exclusion (Tutu and Stoler 2016), water privatization (Dagdeviren and Robertson 2011), and gender roles (Crow and Odaba 2010; Harris et al. 2017), there is limited literature on the explicit linkages between drinking water and health in SSA’s urban slums. In this chapter, we synthesize existing literature, empirical data, and field observations from Malawi, Kenya, Ghana, and Nigeria to highlight current research trends and emerging discussions on the water–health nexus in SSA’s urban slums.

The chapter begins by discussing urban slum ecology in sub-Saharan Africa to highlight features that compound the health consequences of drinking water scarcity. The discussion then draws examples from Malawi, Kenya, Ghana, and Nigeria, supplemented with literature across sub-Saharan Africa to broadly review: water access in urban slums, progress made, and major challenges; the underlying causes, major pathways, and health implications of water contamination; and the role of sachet water as an example of an emerging primary drinking source. The conclusion focuses on highlighting scholarly gaps and research opportunities at the interface of the water–health nexus in urban Africa in the context of continued population growth and rapid urbanization.
Urban Slum Ecology and Health in Sub-Saharan Africa

Urban slum residents are typically vulnerable to myriad poor health outcomes owing to local ecology—broadly defined as the relationship between humans and their physical and ecological environments (Sinha and Sinha 2007). Urban slums are generally characterized by overcrowding, poor sanitation, insecure tenure, and poverty. Shared pit latrines among multiple households are common, open defecation is widespread, and toilet facilities are often woefully inadequate; these factors compound the health consequences of drinking water scarcity (Ramin 2009). While slums are far from homogeneous, it is well documented that deplorable living conditions in overcrowded slum settings significantly facilitate the spread of infectious diseases (Penrose et al. 2010). In SSA, more of the urban population (over 60%) live in slums than is the case in any other region in the Global South (UN Habitat 2013) (Figure 29.1). SSA’s population is also urbanizing faster than any other

![Slum population in urban Africa](image)

**Figure 29.1** Share of urban population in slums in different African countries.

region except Asia, and is projected to increase to 1.2 billion by 2050, almost a three-fold increase from 2010 (Brookings 2015), with much of this growth expected to occur in slum communities.

Nearly 70% of Malawi’s urban population (UN Habitat 2013) and 56% of Kenya’s urban population live in slums (UNSD 2015). Chinsapo slum, shown in Figure 29.2, is the largest slum in Lilongwe, Malawi’s capital city, and depicts a typical landscape for daily life in an African slum. Kenya’s population has increased from 6 million in 1950 to over 46 million in 2015, an average annual increase of 3.2% (UN 2015), with a similar trend seen in other African cities. Much of this growth has been in urban areas, placing increased pressure on formal water supply systems. Supplying safe and reliable water to all residents is a huge challenge in slums owing to factors including rapid urbanization, limited physical space for water infrastructure, disputes over land ownership, poverty, and climate change (CSDH 2008). These challenges are compounded in some cities and informal settlements by a combination of weak governance, poorly coordinated institutions, and insufficient capital investment (Adams and Zulu 2015; Adams et al. 2018; Jimu 2008).

Water Access in Sub-Saharan African Slums

There is severe inequity regarding access to piped water in African cities, as highlighted by data from Mombasa, the second largest city in Kenya. Here, the percentage of people in slums using piped water for drinking was 13% compared to 56% for urban Kenya (KNBS and ICF Macro 2010; KNBS and UNICEF 2009). Access to water in African slums is complex, with interrelated problems regarding quantity, quality, price, and reliability (Dos Santos et al. 2017). The exact mix of

Figure 29.2  Chinsapo, the largest slum settlement in Lilongwe, Malawi.
Urban Slums, Drinking Water, and Health

A given household’s water sources in a typical SSA city or slum is thus shaped by the relative cost of water from improved sources, ability to pay, availability or intermittency of sources, ability to store water (using pumps and tanks), the season, and travel distance and time to unsafe sources (Peloso and Morinville 2014; Smiley 2013). When space constraints or poverty limits ownership of storage facilities or tanks for storing water and guarding against intermittent supply, slum residents often spend considerable time queuing at public taps (Adams 2017).

To cope with these problems, residents of urban slums usually depend on a combination of improved and non-improved water sources. Sources traditionally categorized as improved include piped water to dwelling or yard, public standpipes, boreholes, protected dug wells, protected springs, and rain water, while unprotected springs, unprotected dug wells, carts with tanks, tanker trucks, surface water, vendor-provided water, and bottled water are generally classified as unimproved (WHO and UNICEF 2015).

The slums of Kisumu, the third largest city in Kenya, exemplify the patchiness of household water access. Slums surround the central business district to the north, east, and south, while the western side of the city is bounded by Lake Victoria. The use of multiple water types to meet daily needs has been highlighted in Kisumu’s slums including Nyalenda, Manyatta A, Bandani, and Obunga (Crow et al. 2013; Okotto et al. 2015). Residents in Kisumu choose from a wide array of water sources, including water kiosks, tanker-truck operators, publicly shared taps, hand-dug wells, boreholes, and water-cart vendors (Sima et al. 2013). Residents make daily choices about which type of water to use for drinking, cooking, personal hygiene, washing clothes, and other tasks. Evidence from Kisumu has shown that these decisions are often based on awareness by residents of poor water quality from some sources, and therefore prioritization of specific sources (e.g. piped water) for drinking (Okotto et al. 2015). Water access can also be influenced by the time of year, with rainwater collection during wet seasons undertaken in some slum communities.

In Malawian slums, improved water sources are rare, and thousands of households may be sharing an improved water source that is intermittent or otherwise less reliable. Intermittent supply of water arises from growing water demand coupled with unaccounted-for water (UFW) from leaks in the system (Harawa et al. 2016). Water kiosks, often concrete booths used to store and sell tap water as depicted in Figure 29.3, are the most common source of improved water for many poor urban residents. Each water kiosk may be shared by hundreds of households, a situation exacerbated by irregular availability of piped water during frequent service interruptions. Slum households in Malawi are generally too poor to afford the upfront cost for a private connection, not to mention regular payments of monthly water bills. Even households that can afford connections experience delays by the utility companies (perhaps deliberate given the higher cost of extending piped water infrastructure into high-density neighborhoods), which serves as a disincentive for applying for a meter. Many residents of urban slums consequently turn to unprotected sources owing to an inability to pay for water by the bucket, unnecessarily long waiting times, long distances to water kiosks, and high rates of water kiosk non-function. Unimproved water sources are much more likely to be contaminated (WHO and UNICEF 2015), putting slum residents at increased risk of experiencing water-related diseases. However, access to an improved water source does not necessarily guarantee that a household’s water is safe to drink either (Bain et al. 2014). Slum residents relying on secondary improved water sources delivered at public taps and by vendors sometimes pay more for water of inferior quality (Van Rooijen et al. 2008).

Water Contamination Pathways in Slums

Access to improved sources of drinking water (as defined by WHO and UNICEF 2015) is considered the aim for the global population, yet studies have shown that water from improved sources is not always free from contamination (Shaheed et al. 2014). In a meta-analysis of 319 global studies,
Bain et al. (2014) found that over a quarter of water samples from improved sources harbored some form of fecal contamination, indicating an insufficient barrier between human/animal waste and drinking water. Concerns over the quality of improved drinking water sources are not limited to piped water sources. Some scholars have been critical of the quality of water in cities and slums from vendors (cart with tank and tanker trucks) (Machdar et al. 2013). Cross-contamination of small drinking water reservoirs and storage vessels can occur in many ways and is often driven by the interaction of impervious surfaces with local hydrology, which can severely reduce water infiltration and facilitate runoff (Nyenje et al. 2013).

Common sources of water contamination in African slums include backflow and seepage into cracks in the piped water network (exacerbated by intermittency and poor pressure), poorly designed or managed sanitation facilities (e.g. open defecation or pit latrines without a slab), landfills and other waste dumps, animal waste, urban agriculture, laundry washing, car washing, industry, and pharmaceuticals (e.g. Ezeh et al. 2017; Kimani-Murage and Ngindu 2007; Kimani-Murage, Schofield et al. 2014; K’oreje et al. 2016; Okotto-Okotto et al. 2015; Opisa et al. 2012; Wright et al. 2013). Indiscriminate waste disposal due to either poorly designed or nonexistent sanitation systems in Malawian slums is a pressing public health problem and remains a significant avenue for water contamination (Palamuleni 2002). Shallow wells, for example, are very important alternative sources of water in urban Malawi, yet often prone to contamination from sewage runoff (Msilimba and Wanda 2013; Pritchard et al. 2007). Household dependence on nearby rivers and lakes for drinking, laundry, and other uses remains a public health concern (Figure 29.4). Shallow wells in high-density areas in Malawian cities are prone to high fecal coliform concentrations (Chidya et al. 2016). While not systematically investigated, cross-contamination of water

Figure 29.3 Residents waiting for water in an urban slum in Lilongwe, Malawi. Water fetching is still mostly performed by women and girls.
supplies can also occur through unsanitary conditions at the water kiosk, such as: proximity to gutters, agricultural plots, or roaming livestock; improper rinsing or handling of storage containers; and lack of personal hygiene by kiosk operators.

The main contamination pathways from water source to the point of drinking are described in Figure 29.5. Contamination can occur at the source, at the point of water collection, during transport, and during storage of water (Rufener et al. 2010; Satapathy 2014). Evidence from slums in Kenya has shown contamination of water sources available to residents in Nairobi (Blanton et al. 2015), Kisumu (K’oreje et al. 2016; Okotto-Okotto et al. 2015; Opisa et al. 2012; Wright et al. 2013), and Eldoret (Khazenzi et al. 2013; Kimani-Murage and Ngindu 2007), frequently due to inadequate management of human waste disposal. One of the few long-term studies of water quality in African slums was undertaken in Kisumu in Kenya. In a study of 263 water samples taken from 61 groundwater sources between 1998 and 2004, researchers found that most samples had unsafe levels of fecal coliforms, fluoride, and nitrate (Wright et al. 2013). In a follow-up of Wright et al.’s (2013) work, Okotto-Okotto et al. (2015) investigated how water quality had changed between 1998 and 2014. The researchers found that contamination risks increased in response to urbanization and increased latrine density; however, water quality showed a more complicated pattern of change, possibly related to rainfall. This again highlights the importance of seasonality in the contamination of water. A typical shallow well in an informal settlement observed by Okotto-Okotto et al. (2015) highlights multiple contamination risks including surface water pooling around the well, waste dumping, lack of a well cover, and a dipping bucket left open to contamination (see Figure 29.6).
Potential water treatment

Other improved drinking water sources: public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs, rainwater collection.

Unimproved drinking water sources: unprotected dug well, unprotected spring, cart with small tank/drum, tanker truck, bottled water

Surface drinking water sources: river, dam, lake, pond, stream, canal, irrigation channels

Potential contamination, e.g. waste dumps, animal waste, unimproved sanitation, car washing

Piped water on premises: piped-water to dwelling, plot or yard

Piped water on premises: piped-water to dwelling, plot or yard

Potential contamination, e.g. storage in dirty containers, open containers, handling with unwashed hands

Potential contamination, e.g. unimproved sanitation facilities, animal waste and waste dumps

Figure 29.5  Potential water contamination pathways in SSA informal settlements. 
Source: Adapted from diagrams in Rufener et al. (2010) and Satapathy (2014).

Figure 29.6  A shallow well in an informal settlement of Kisumu, Kenya. 
Photograph © Steve Pedley.
Studies undertaken in Malawian slums have yielded similar findings. Significant inequities in the distribution of drinking water contamination across low-income and high-income urban settlements of Lilongwe, Malawi’s capital city, have been observed (Boakye-Ansah et al. 2016). Evidence from the slums of Mzuzu, the third largest city in Malawi, found household drinking water samples contaminated with *E. coli* concentrations significantly above World Health Organization guidelines (Holm et al. 2016). Contamination is higher in the wet season owing to high mobility of contaminants through rainfall and surface runoff, as observed in Blantyre, Malawi (Pritchard et al. 2007). If implemented correctly, point-of-use water treatment (including chlorination, solar water disinfection, or ceramic filters) removes microbiological pathogens and reduces the likelihood of many adverse health impacts from drinking contaminated water (Clasen et al. 2007). Treatment of water from non-improved water sources is common in some slums; however, the application of treatment methods, such as filtration, settling, and solar disinfection, has not always been effective (Cherunya et al. 2015; Okotto et al. 2015).

### Water and Health in African Slums

The health effects of inadequate safe water in African slums are catastrophic, particularly for the most vulnerable residents. These include the classic Bradley classification of water-related diseases: waterborne diseases associated with ingesting pathogens via drinking water, water-washed diseases associated with hygiene and low quantity of water, water-based diseases associated with ingestion or contact with disease agents that spend part of their life cycle in water, and diseases with water-related insect vectors that typically breed in or bite near stored or standing water (Bartram 2015). Slum dwellers may also face adverse health issues associated with industrial chemical pollution, natural chemical pollution (arsenic, fluoride, etc.), musculoskeletal health issues from water fetching, and poor water aesthetics, as well as indirect health risks via lower socio-economic status from insufficient access to water for livelihood purposes (Hunter et al. 2010), and hazards such as flooding associated with sea-level rise in coastal areas (Adelekan 2010). While all of these factors affect slum residents, the health burdens most frequently associated with unsafe drinking water in urban slums are waterborne illnesses.

Consumption of unsafe water has been linked to numerous health problems, including diarrhea, cholera, hepatitis A, typhoid, polio, and dysentery (WHO 2016). The most common and widespread of these diseases in slum communities is diarrhea. In 2012, worldwide access to inadequate water was responsible for an estimated 502,000 premature deaths from diarrhea (Prüss-Ustün et al. 2014). Slum communities by their ecology are at relatively higher risk of diarrhea through water contamination. Lilford et al. (2017) mapped risk of diarrhea in children under five years old across Nairobi in Kenya and found that the highest risks were in the slums within the city, particularly Kangami, Kawangware, and Mathare/Huruma. Diarrhea is especially problematic for children, since their immune systems are not yet fully developed. In Kenya, infant (0–11 months), child (12–59 months), and under-five mortality rates (per thousand live births) were all higher in urban slums when compared to urban and rural areas (Kimani-Murage, Fotso et al. 2014), and this difference was attributed largely to poor water and sanitation access in slums. While diarrhea prevalence for slum children in Kenya appears to be gradually decreasing (APHRC 2002; KNBS et al. 2015; NCPD et al. 1999), a 2012 study of health within the slums of Nairobi (APHRC 2014) found that a significant proportion of children (20%) had had diarrhea in the two weeks preceding the survey. In Malawi, scholars have found that seasonal differences tend to affect waterborne illness prevalence in urban slums, with diarrhea and cholera being more common during the wet season (Khonje et al. 2012).

Water-related vector-borne diseases are also important sources of illness when urban slums are located near small water bodies, and more commonly due to unsafe household water storage and
transportation practices. Water bodies like ponds and rivers, as well as irrigation canals for urban agriculture, can provide breeding habitat for *Anopheles* mosquitoes that transmit malaria. While malaria is well studied in Africa, mosquito-borne diseases associated with different species are emerging in SSA (Stoler, al Dashti et al. 2014). The use of unsealed water storage containers in and around the home—a normal part of the landscape in water-stressed slums—presents a perfect breeding habitat for *Aedes* mosquitoes that spread a variety of viral fevers (e.g. yellow fever, dengue, chikungunya, and Zika), and *Culex* mosquitoes that spread West Nile virus and several forms of viral encephalitis. The buildup of uncollected trash left behind by inadequate (or nonexistent) sanitation services provides even more places for *Aedes* and *Culex* mosquitoes to lay eggs after rainy periods. The high density of human hosts in urban slums offers easy targets for biting mosquitoes and flies, and facilitates the rapid spread of vector-borne diseases if slum communities lack vector control knowledge and resources. Slum communities in Accra, Ghana have been shown to have low knowledge of mosquito-borne disease transmission and sometimes perceive all mosquitoes as potential vectors of malaria (Jankowska et al. 2015).

Additional health risks are associated with the transport of water from source to the household (Boateng et al. 2013). Women and girls who are committed to finding water for their families expend considerable energy by walking long distances to and from water sources, as well as spending considerable time waiting for water. This underscores the need to incorporate the full cost of water fetching in low-income countries, especially given the inevitable effect of caloric expenditure on health (Sorenson et al. 2011). Water transport also has a big impact on people’s time, with single or multiple daily trips presenting huge opportunity costs such as missed opportunities to engage in paid work, or young girls missing school. The United Nations estimates that women and girls spend up to six hours every day fetching water (UN 2013). The health implications associated with the physical strain of walking to fetch water and head-loading water have not been thoroughly explored, although a few studies in SSA show that carrying water by head-loading may be associated with spinal pain and neck and other muscular-skeletal injuries (Geere et al. 2010). It is not uncommon to see women and girls in African countries—Malawi and Kenya included—carrying heavy containers of water in wheelbarrows (Porter et al. 2013). Even so, the long-term consequences of water fetching due to physical strain remain understudied across SSA.

**Sachet Water Comes of Age in West Africa**

In West Africa, privately vended drinking water has experienced a rapid transformation over the last two decades: a large part of the urban population now drinks from mechanically sealed 500 ml polypropylene bags of drinking water known as sachet water (Figure 29.7). Since its introduction in 1996, sachet water has grown into a multibillion-dollar industry and become a consumer sensation throughout West Africa. In cities such as Lagos and Accra, poor water governance, infrastructure neglect, and rapid population growth and urbanization led to soaring demand for fresh water that far outstripped supplies even where municipal systems existed (Nsiah-Gyabaah 2001; Olukoju 2007). Subsequent municipal water rationing exacerbated this gap, which was ultimately filled by private sector innovation in the form of sachet water (Stoler, Fink et al. 2012). Perhaps no drinking water technology has proven more commercially successful.

Sachet water will likely play an important role in sub-Saharan Africa’s achievement of Sustainable Development Goal 6 for “universal and equitable access to safe and affordable drinking water for all,” though with significant dependencies related to industry maturity, plastic waste management, and state governance. But the interdisciplinary literature on sachet water suggests recent progress in product quality that bodes well for sachet water’s potential to improve water security and human health across the region.
While households often patch together water from a variety of sources, the number of households relying on sachet water as a primary—rather than supplemental—drinking source is on the rise. The best available data on sachet water consumption come from Ghana, where multiple national-level surveys have begun tracking it as a primary drinking water source. The 2010 Ghana Census found sachet water to be the primary drinking water source in 9% of households nationally (13.9% and 2.8% respectively for urban and rural households) and 28% in Greater Accra, the nation’s urban seat (Ghana Statistical Service 2013). The 2012–13 Ghana Living Standards Survey 6 found sachets to be the primary water source for nearly 20% of 2,972 surveyed households (Wright, Dzodzomenyo, Wardrop et al. 2016).

The 2014 Ghana Demographic and Health Survey (DHS) also found sachet water to be the primary drinking water source for 29% of households, with rates of 43.1% and 11.8% for urban and rural households respectively (GSS, GHS, and ICF International 2015). In Nigeria, the 2013 DHS found sachet water consumption to be the primary water source for 5.8% of all households (12.0% for urban and 1.1% for rural households). These lower rates still represent a larger absolute number of sachet consumers than in Ghana, given Nigeria’s size, even though Nigerian households continue to primarily rely on wells and boreholes (NPC and ICF International 2014).

The notion of sachet as a primary drinking water source also masks the true popularity of sachets across West Africa, as the product is popular for its portability and convenience even among citizens who have access to another water supply (Stoler, Tutu, and Winslow 2015). Community-level household surveys commonly reveal percentages approaching 100% that “ever” drink sachet water (Grönwall 2016). All of this sachet consumption represents a potential shift away from less wholesome sources of drinking water by solving the “safe water storage” problem in West Africa.

**Figure 29.7** Two typical brands of sachet drinking water in Ghana. This low-cost form of packaged water has become big business throughout West Africa.
Additional unintended consequences include limiting stored water that serves as breeding opportunities for mosquitoes and flies that transmit disease. The quality of sachet water has not been reliable until very recently, and may now be viewed as a sort of accidental drinking water intervention in urban areas.

The microbiological and physico-chemical qualities of sachet water have historically been the most investigated aspects of sachet water. A 2012 review of sachet water quality summarized 30 studies through 2010, which predominantly focused on the levels of microbiological indicator organisms, such as *E. coli*, and heavy metals as proxies for health risk (Stoler, Weeks, and Fink 2012). This early literature is also replete with problems such as inadequate sample size, geographical coverage, or control of confounding variables related to storage and handling (Stoler, Weeks, and Fink 2012). Sachet water has had a dubious reputation, with many examples of contamination reported around the world, particularly in Africa (Williams et al. 2015). Sachet water was suspected of helping drive Lagos’s infamous typhoid outbreaks in the 1990s (Olukoju 2007) and recent cholera outbreaks in Accra (Dzotzi et al. 2015). Sachet water continued to stay off the major development agencies’ radar owing to its poor reputation and the relatively tiny volume of water trading relative to the volume distributed via piped water systems.

The number of published sachet water quality studies from West Africa has tripled since 2010 and become more nuanced in content. A review identified 69 new studies from West Africa published between 2011 and 2016 (Stoler 2017). As of 2010, there was little recognition of how the sachet water supply chain might affect water quality and safety. Between 2011 and 2016, there were studies assessing the effects of production handling, packaging, sunlight, storage, temperature, and brand on sachet quality, as well as the presence of radioactivity, phthalates, and antibiotic resistance (Stoler 2017). The first studies of African sachet water produced outside of Nigeria and Ghana have also appeared in the last five years, with mixed findings coming from: Bissau, Guinea-Bissau (Bordalo and Machado 2015); Abidjan, Côte D’Ivoire (Manizan et al. 2011); Freetown (Fisher et al. 2015) and Bo City, Sierra Leone (Kamara et al. 2016); Kinshasa, Democratic Republic of the Congo (De Boeck et al. 2012); and Kampala, Uganda (Halage et al. 2015).

The most representative regional examination of sachet water quality was included in the 2012–2013 Ghana Living Standards Survey 6, which included a water quality module and tested 3,096 drinking water samples nationwide. That study found packaged water (both bottled and sachet) to have the lowest risk of *E. coli*, perhaps offering protection against point-of-use contamination and offering an inadvertent public health benefit (Wright, Dzodzomenyo, Wardrop et al. 2016), as previously suggested in a study of sachet water in low-income Accra neighborhoods (Stoler, Fink et al. 2012). Cohorts of individuals who primarily rely on sachet water now exist as potential study participants in most West African cities, enabling future trials of sachet water’s health effects. This is important progress given the mountain of evidence that drinking water interventions improve human health in low-income settings around the world (Fink et al. 2011; Wolf et al. 2014). The mass consumption of high-quality filtered water may also introduce new long-term health concerns such as micronutrient deficiencies that have previously been linked to conditions such as hypertension and heart disease (Akpoborie and Ehwarimo 2012), though these are secondary to the health risks presented by the consumption of contaminated water. Another research frontier is the long-term health risks associated with plastic leachates in drinking water, given that sachet water often spends parts of its life cycle—particularly delivery and point of sale—in extreme heat under the equatorial sun (Stoler 2017).

The industrialization of the sachet water industry seems to have caused an inflection point in product quality sometime around 2010–2012, likely owing to more hygienic production environments. Several recent studies have concluded sachet water to be within regulatory thresholds for the organism or compound tested (Asamoah and Amorin 2011; Linda et al. 2016; Stoler, Tutu et al.
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2014; Stoler, Ahmed et al. 2015) or at least the safest of all locally available drinking water options (Fisher et al. 2015; Wright, Dzodzomenyo, Wardrop et al. 2016). A global review of fecal contamination of all drinking water sources in low- and middle-income countries found that bottled water and sachet water were typically high-quality (Bain et al. 2014). Another global review of fecal contamination specifically in packaged water concluded that bottled water and sachet water were of better microbial quality than any other available water sources, including tap water (Williams et al. 2015). Nigeria has experienced slower industry maturation and greater regulatory challenges given its size, and thus we continue to see poor sachet quality reflected in Nigerian studies (Oludairo and Aiyedun 2015).

In an effort to test new public–private partnership models for sachet water, an ongoing trial in Accra is piloting a subsidization program of sachet water for low-income households with young children and measuring changes in water consumption (Wright, Dzodzomenyo, Fink et al. 2016). Preliminary findings show that a voucher for 15 L/week/child of free sachet water was significantly associated with an increase in sachet water consumption of 0.27 L/child/day, thus potentially improving the quality of drinking water consumed by children, and opening the door to potential health improvements. Right now this trial is a theoretical exercise. But the potential formalization of sachet water as a low-income water source by governing institutions in such a scheme would bring a whole set of questions to the forefront about the ability of sachet water to reduce water insecurity given the historically ephemeral nature of Ghana’s water governance. This trial also addresses none of the regulatory or sanitation and plastic recycling issues that prevent sachet water from being a sustainable water source in the spirit of the SDGs. Private sector participation in the piped water sector has been shown to improve child health in a study of child-level data from 39 African nations from 1986 to 2010 (Kosec 2014), so the tradeoffs of sachet water distribution must be weighed carefully.

Several trends have important implications for reducing water insecurity as Sachet water spreads across Africa. The corporate producers are located in the largest cities, and thus the best sachet water quality has been observed in urban areas with high competition and shorter product travel times. Because the larger corporations can afford to enforce more stringent quality control (and have more to lose), they are also generally easier to regulate. These factors bode well for water availability in urban slums, but with caveats. Slum residents remain vulnerable to price shocks associated with the private sector’s response to poor water governance. Plastic waste management also continues to be a significant challenge for the sachet water industry, as waste management infrastructure investments have lagged well behind the inadequate investments in water infrastructure that opened the door for sachet water, though some recycling efforts have gained traction (Stoler 2017). The plastic wrappers routinely clog urban gutters during heavy rains and cause open sewers to flood, thus exposing residents to a variety of health risks (Stoler, Weeks, and Fink 2012). Finally, there is still virtually no conclusive evidence about health risks related to plastic leachates associated with handling, transportation, and storage (Figure 29.8). With sachet water increasingly being transported across greater and greater distances, including international borders, manufacturers and distributors need to understand the nature of potential bacterial regrowth and leaching in these longer supply chains.

Interest in sachet water quality has dramatically increased over the last few years, and scholars have a much clearer picture of sachet water quality, particularly in West Africa. As the sachet water industry matures, one of the keys to quality control will be governing institutions’ ability to promote and enforce a regulatory environment with appropriate incentives for the protection of public health. This should be part of a coherent vision for improving drinking water access across the continent, as sachet water appears to have become a permanent part of the waterscape. While sachet water has undoubtedly improved water security in urban slums of West Africa, its potential to become a sustainable drinking water source remains controversial.
Conclusion

This chapter has introduced readers to the complex linkages between drinking water access and health in urban slums of SSA. We drew insights from field observations in Malawi, Kenya, Ghana, and Nigeria, and literature from other countries to examine trends, share lessons, and outline potential research directions on the interactions between urban slum ecology, drinking water, and health. The observations highlighted in the chapter reflect experiences across the SSA region; poor access to water is compounded by, among other factors, population growth, rapid urbanization, increasing demand, inadequate and ailing water infrastructure, weak governance, and insufficient political will. In the urban slums of SSA, poor access to safe drinking water predisposes residents, especially children, to diarrhea, cholera, and other water-related conditions. Even improved water sources, as defined by WHO and UN standards, are prone to contamination owing to unsanitary conditions, water transport, and dirty storage containers. Based on the findings in this chapter, we recommend several areas for further research.

We have highlighted a number of studies that have found evidence of contamination in water supplies consumed by slum residents. Many of these studies were cross-sectional, thus failing to capture short- or long-term temporal changes in population risk (Kostyla et al. 2015). Consequently, many more robust water quality studies (both temporally and spatially) are needed in slums. The development of lower-cost water quality sensors (and networks of these sensors) will help here. These studies should take place not just at the source but also within the household to improve our understanding of the impact of water transport and storage on water quality.
There is a need for more thorough investigation of the right metrics and indicators to examine the scale and complexity of water security in slums. Many, including Smiley (2013), have noted that standard metrics of water access do not accurately capture the magnitude of water access in urban slums of SSA. Access to an improved source does not imply the continuous availability or reliability of the source; and an improved source is not always free of contaminants. Current global water access monitoring programs do not capture the complex spatio-temporal dynamics of water access in SSA’s urban slums. More studies focusing on the fine-scale temporal dynamics of access for slum residents are needed to address this gap.

Prior studies, while limited, show that interruptions to water supply may facilitate waterborne pathogen infection in at least two possible ways: first, by people reverting to unsafe water consumption (Hunter et al. 2009) and, second, via pressure changes in water-distribution networks, which can influence the frequency of contamination (Besner et al. 2011). This lacuna presents opportunities to explore the health-related consequences of poor water-service delivery and supply interruptions in the urban slums of Africa.

With projected large increases in population numbers in SSA, particularly in urban areas, there is an urgent need to improve our understanding of the water–health nexus in urban slum environments in SSA. In particular, there are uncertainties around water technologies, water access, emerging pathways and likelihood of infection, and implications for slums. Given our understanding that improved sources may still be prone to contamination, the question remains which improved sources of water are more likely to be contaminated and why. Recent work shows that the distribution of microbial contamination in urban slums is spatially unequal (Boakye-Ansah et al. 2016). Possible related questions include what factors could best explain unequal spatial distribution of microbial contaminants in slum environments and how consequences are distributed. Under-five mortality rates are generally higher in the urban slums of Africa compared to other parts of cities (Taffa and Chepngeno 2005). While this high incidence may be due to a large spectrum of factors, including air quality, nutrition, and other diseases not directly related to water contamination, it remains unclear the extent to which cases in slums can be linked directly to waterborne diarrhea and cholera within these urban settlements, though some evidence is beginning to suggest this (e.g. Lilford et al. 2017).

Finally there is the need to better understand the popular appeal and spatial diffusion of emerging drinking water technologies, such as sachet water, that may yet disrupt traditional urban drinking water schemes and interventions. While sachet water has been an urban phenomenon, it is unclear if this water source can be sustainable over larger geographic regions and lower-population-density rural areas. The packaged water industry remains in its infancy in SSA, and privatization of drinking water is thus poised to grow throughout the region as water resources are increasingly stressed as a result of climate change.

The ability of many African nations to achieve universal access to safe drinking water for all, including urban slums where access rates are already very low, largely depends on willingness to integrate new innovations into the drinking water sector as well as legal recognition from local governments and capital investments in water, sewage, and drainage infrastructure. Sub-Saharan Africa did not achieve its MDG target for drinking water access. Achieving the new SDG target will require multiple strategies, including a renewed emphasis on monitoring and evaluation. Strong political will is needed to responsibly institutionalize alternative water sources (e.g. sachet water) while implementing measures to ensure that new sources remain free of contamination in the long term. This is even more important when considering that extending piped water to every home in urban slums is often infeasible in the short term because of the massive capital investments required, coupled with variable prospects for cost recovery. Coordination and integration of views from all relevant stakeholders in the water and health sectors—especially slum community representatives—at multiple scales are imperative for drinking water interventions to make any meaningful impact on the health of urban slum residents across Africa.
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