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COVID-19 lockdowns: Employment and business disruptions, water access and hygiene practices in Nairobi's informal settlements

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ABSTRACT

Host to one billion people around the world, informal settlements are especially vulnerable to COVID-19 lockdown measures as they already lack basic services such as water, toilets, and secure housing. Additionally, many residents work in informal labor markets that have been affected by the lockdowns, resulting in further reductions in access to resources, including clean water. This study uses a cross-sectional design (n = 532) to examine the vulnerabilities of households to employment and business disruptions, water access and hygiene practices during the COVID-19 lockdowns between April and June 2020 in three informal settlements in Nairobi, Kenya. We used survey questions from the Household Water Insecurity Experience Scale (HWISE) to investigate the relationship between employment and business disruptions, water access, and hygiene practices (i.e., hand washing, body washing, clothes washing, and being able to use or drink clean water). Of the sampled households, 96% were forced to reduce work hours during the lockdowns, and these households had 92% lower odds of being able to afford water than households who did not experience a work hour reduction (OR = 0.08, p < .001). Household challenges in affording water were likely due to a combination of reduced household income, increased water prices, and pre-existing poverty, and were ultimately associated with lower hygiene scores (Beta = 1.9, p < .001). Our results highlight a compounding tragedy of reduced water access in informal settlements that were already facing water insecurities at a time when water is a fundamental requirement for following hygiene guidelines to reduce disease burden during an ongoing pandemic. These outcomes emphasize the need for targeted investments in permanent water supply infrastructures and improved hygiene behaviors as a public health priority among households in informal settlements.

1. Introduction

The COVID-19 pandemic has exposed chronic gaps in water supply and sanitation services, especially in low-income areas. More than 2.2 billion people lack access to adequate water and do not have the option of practicing regular handwashing (Anim and Ofori-Asenso, 2020; Lof-tus and Sultana, 2020). Moreover, efforts to stop the spread of COVID-19 and related economic impacts are affecting people's access to water. As a result, one in three people surveyed in five sub-Saharan African

countries faced new challenges to accessing water due to the pandemic, including struggling to afford water (USAID, 2021).

Informal settlements are highly vulnerable to the impacts of COVID-19 lockdowns on water access, as they already lacked adequate access to water before the onset of the pandemic (Corburn et al., 2020; Grasham and Neville, 2020). These communities may face severe water insecurity because a majority of them also work in informal labor markets where income is uncertain or irregular, and many residents therefore live 'hand to mouth' (Chirisa et al., 2020). According to the World Health

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Organization (WHO), a person needs between 50 and 100 L of water per day to ensure their basic needs (Howard et al., 2003). Even in normal circumstances, informal settlements face barriers to accessing safe and sufficient quantities of water, one such barrier being the high cost of water relative to income (Bisung and Elliott, 2018; Stoler et al., 2020). Market closures and curfews have led to a reduction in working hours and labor earnings (Danquah et al., 2020), exacerbating existing challenges of water affordability. One recent study found that by the end of April 2020, one out of four workers surveyed in Burkina Faso, Mali and Senegal had lost their jobs, and one out of two workers in these countries had experienced a decline in earnings as a direct consequence of COVID-19 lockdowns (Balde et al., 2020). This is significant, as even a modest reduction in income due to lockdown-induced employment and business losses can introduce challenges for informal settlement households, which spend a large proportion of their income (ten percent) on acquiring water.

In addition, a majority of people living in informal settlements depend on informal water providers such as street vendors, water resellers, kiosks and water tankers to fulfill their water needs (Ahlers et al., 2014; Garrick et al., 2019; Raina et al., 2019). In the absence of household-level municipal piped water access (Winter et al., 2021), individuals living in informal settlements must leave their homes to purchase water from these vendors daily. As such, the very nature of water access in informal settlements makes it challenging to reliably source adequate quantities of water during mobility restrictions and curfews (Wasdani and Prasad, 2020). Water sold by informal water providers is already expensive and of compromised quality (Price et al., 2021), carries a high risk of water-borne disease infection (Kangmenang et al., 2020; Subbaraman et al., 2013), and is associated with excess time burden and emotional distress among poor populations (Brewis et al., 2019). In addition, water service providers themselves are struggling to maintain a reliable supply of water to informal settlements due to rising costs and uncertainty regarding the safety of their operations during the pandemic (USAID, 2021).

The COVID-19 pandemic has thus injected several shocks into the already stressed households and water supply systems in informal settlements. The Joint Monitoring Program (JMP) found that approximately 20–40% of survey respondents in five countries in Sub-Saharan Africa experienced disruption of drinking water services during the pandemic (WHO, 2021). In addition to basic needs, this reduced access to water makes it difficult for households to maintain hygiene practices such as hand washing that are deemed important during the ongoing pandemic (Anim and Ofori-Asenso, 2020; Jiwani and Antiporta, 2020). Although evidence suggests that the risk of COVID-19 spreading from fomite surfaces to hands, and from hands to mucous membranes is low (CDC, 2021; Lewis, 2020), according to the WHO, handwashing is one of the most effective and preventative health interventions for infectious disease control (CDC, 2021; Olapeju et al., 2021). Most importantly, in places with limited resources and poor healthcare infrastructure such as Sub-Saharan Africa, handwashing behavior plays a critical role in saving lives (UN-Habitat, 2020; WHO, 2021). Household inability to maintain adequate hygiene practices is already associated with existing health threats such as cholera and typhoid in informal settlements (Mushavi et al., 2020), and the introduction of COVID-19 infections therefore places an added burden on healthcare facilities. As such, maintaining affordable and adequate water access, hygiene practices and good health, alongside sustaining livelihoods, represent considerable challenges unique to informal settlements during the ongoing pandemic.

The aim of this study is to investigate the relationship between COVID-19-related employment and business disruptions, household water access, and hygiene practices in three informal settlements - Mukuru Kwa Njenga, Kwa Reuben, and Viwandani in Nairobi, Kenya. We conducted a structured survey of households by phone interviews during the government-imposed lockdown restrictions in Nairobi from April to June 2020. The paper investigates water security and hygiene practices during the lockdown period of the pandemic, shedding light on

conditions in an informal settlement context. In doing so, we assess the relationships between three types of employment and business disruptions and self-reported affordability of water: (1) loss of own business/enterprise, (2) reduction in work hours, and (3) ability to find alternate employment in instances of business or work loss. Further, we examine four hygiene practices, including washing hands, bodies, and clothes, and using/drinking clean water, and their relationship to the availability and affordability of water during the lockdowns. We ask.

- (1) What was the relationship between employment and business disruptions, and household ability to afford water during the lockdowns?
- (2) What was the relationship between water availability, affordability, and hygiene practices during the lockdowns?

Whereas the impacts of pandemic-related employment disruptions on economies, food security and mental health are well documented (Laborde et al., 2020; Posel et al., 2021), this study documents the interlinked vulnerability of informal households to water access and hygiene practices in the context of employment and business loss. The results could inform future policy responses within these often-marginalized informal settlements, where the fragile water provision systems have failed to meet all residents' needs since long before the pandemic.

2. Methods

Research context: Kenya implemented a partial lockdown on April 6, 2020, followed by a nationwide curfew from 7pm to 5am and ceased mobility in informal settlements in Mombasa and Nairobi (Quaife et al., 2020). Mobility restrictions and employment losses disproportionately impacted the 55% of Nairobi's population that lives in informal settlements (Mwau et al., 2020). In terms of water access, more than 80% of households in informal settlements rely entirely on informal water providers in Nairobi, who price water four times higher than municipal water tariffs (Crow and Odaba, 2009; Nilsson and Nyanchaga, 2008). In addition, informal water providers use make-shift infrastructures such as plastic pipes to transport water. These pipes can leak, making cross contamination from sewage water common and, in turn, making it difficult to access water that is clean and pathogen free (Kimani-Murage and Ngindu, 2007; Sobsey et al., 2003).

The settlements of Mukuru Kwa Njenga, Kwa Reuben and Viwandani compose one of Nairobi's largest informal settlements located in the industrial zone on the southeastern periphery of the city (Fig. 1). The three settlements are home to 351,702 residents and 143,061 households. The estimated number of households per settlement in Mukuru Kwa Njenga, Kwa Reuben and Viwandani are 97,890, 26,699, and 18,472 respectively (Kenya National Bureau of Statistics, 2019).

In terms of water provision, the Nairobi Water and Sewerage Company (NCWSC) formally supplies water to very few businesses and households (~2%) in the settlements. Specifically, 97% of residents in Mukuru settlements access water solely from informal water providers that supply water for profit (Sdi.Kenya & AMT, 2017). Many households walk up to informal tap-points or tanker-trucks, collecting water in barrels that cost between US\$ 0.05–0.5 (Ksh 5–50) per 20-L barrel; some have access to shared tap-points in yards, for which they pay the homeowners on a weekly basis (Corburn et al., 2017). Other water sources recognized as formal or public sources by Mukuru residents are from community youth groups, non-governmental organizations (NGOs) and government boreholes that provide water for free or at a constant price of US\$0.03 (3 Ksh) per 20-L barrel (IIED & Sdi.Kenya, 2020) (Table 1). In April 2020, the Nairobi Metropolitan Services (NMS) began providing free, intermittent water assistance on a first-come, first-served basis through tanker trucks to help people maintain hygiene practices during the pandemic and help increase hand washing in the settlements (Kimatu, 2021).

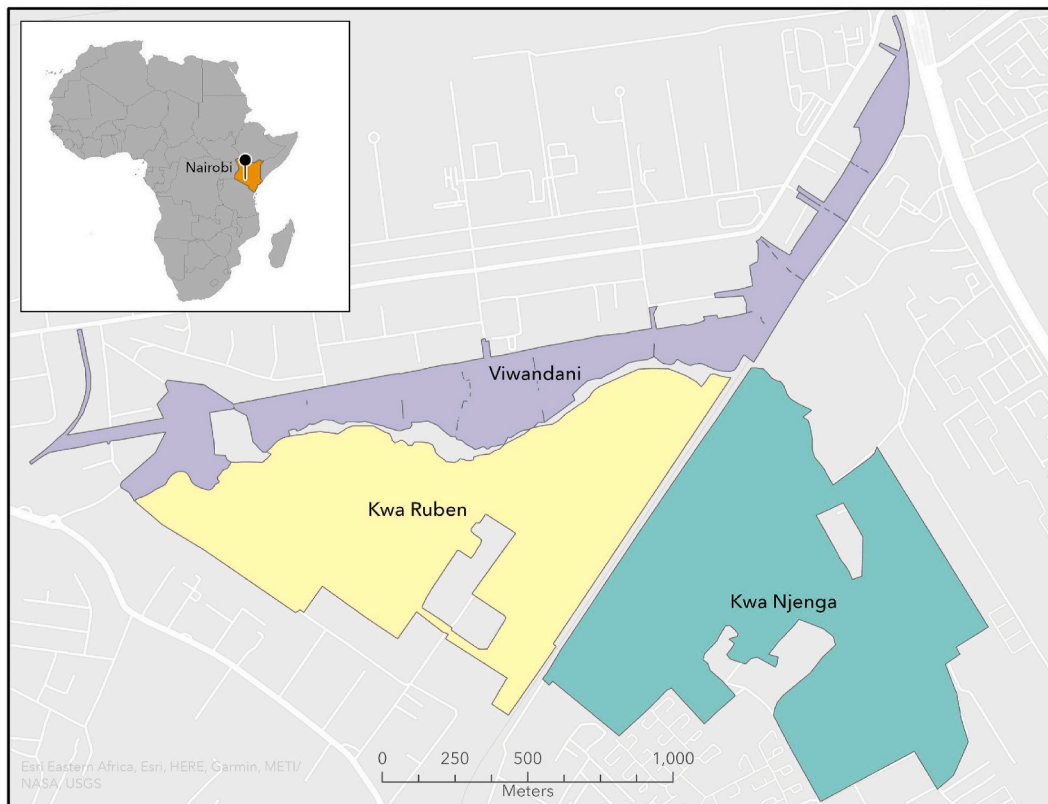


Fig. 1. Informal settlements of Mukuru Kwa Njenga, Kwa Reuben and Viwandani.

Table 1
Types of water provision by formal and informal sources in the sample population.

	Formal Water Sources	Informal Water Sources
Tap-points	Tap-points maintained by NGOs and community youth groups; government boreholes (~0–3 Ksh)	Individual private water providers (~5–50 Ksh)
Tanker-trucks	Nairobi Metropolitan Services (free water assistance)	Individual private water providers (~5–50 Ksh)

Study design and sampling: We used a cross-sectional survey design, where sampling took place in person in 2019 and surveys were administered remotely in 2020. In the summer of 2019, the lead author randomly sampled households to participate in the study by obtaining consent to be contacted in-person or via phone to participate in the study. Contact information from 700 households were collected. To control for spatial autocorrelation in the dataset, the lead author ensured that households were spatially distributed across each settlement by skipping 10 houses and sampling the 11th house at each major road transect. This systematic sampling approach of skipping households and sampling them from each transect road provided a representative sample of households in the study sites.

Due to the COVID-19 pandemic in 2020, the research team proceeded to collect data remotely via a household survey. We contacted the 700 households that were sampled in 2019 by phone. Of these, we were able to reach 635 sampled households by phone. Of these 635 households, 540 households (i.e., 85% response rate) consented to participate in a phone call survey according to our informed consent guidelines. The research team administered surveys to an adult (>18 years of age) in the household who self-identified as being knowledgeable about the household’s water access and livelihood information. We further excluded eight observations from our analysis due to missing values, resulting in a complete set of data for 532 households.

Data collection procedures: Our local research team collected survey data via phone in the study sites in July 2020. The team consisted of three enumerators fluent in Kiswahili and Kikuyu that had previous in-person data collection experience over several field campaigns with our research team. We held online training sessions with these three enumerators in June 2020 and we piloted the survey instrument with 13 households before finalizing our data collection protocols. The enumerators then collected survey data via phone calls in the study sites using a digital device and entered responses in a Qualtrics survey. Each survey took approximately 30–35 min to complete.

Ethical adherence: We obtained Institutional Review Board approval from our institution, research permit from the Kenya National Commission for Science, Technology and Innovation (NACOSTI), as well as an affiliation with a local university to conduct human subjects-based research according to data collection protocols and ethical research standards.

3. Measures

Our survey instrument had two recall periods, which included ‘the last four weeks’ and ‘since April’. Therefore, our study measures household experiences for the month of June and during the period April–June 2020. A summary of the survey questions and measures used in the analysis of this paper are presented as follows.

Employment disruptions: Three types of employment disruptions were measured at the household level: (1) whether household member(s) were forced to stop business due to lockdowns, (2) work less hours (either for themselves or an employer), and (3) found alternate employment in the case of work reduction or loss. Respondents were given discrete answer choices between yes, no and does not apply. We used the recall period of “since April” and emphasized “because of COVID-19 pandemic lockdowns” in our questions to capture the lockdown induced disruptions rather than usual changes in employment status. The aim was to understand if household members had faced

employment disruptions due to the COVID-19 lockdowns since April 2020.

Water availability and affordability: We measured household access to water in terms of two aspects: (1) self-reported affordability, and (2) availability. These measures were derived from the following questions in the Household Water Insecurity Experience Scale (HWISE): (1) In the last four weeks, how frequently have you or anyone in your household lacked the money needed to buy water? (2) In the last four weeks, how frequently have you or anyone in your household wanted to buy water but there was nowhere to buy it from? We modified the same questions and also asked them using the ‘since April’ recall in the survey. We did not compare these two periods “since April” and “last 4 weeks” with each other: the two time periods pertain to two different sets of questions that help us understand the status of water security in the study sites during the lockdowns. The responses for the questions were as follows: *never* (0 times), *rarely* (1–2 times), *sometimes* (3–10 times), *often* (11–20 times), or *always* (more than 20 times) (see Young et al., 2019 on development of the scale). In the analysis stage, we combined the *often* and *always* categories into *often/always* as suggested by the developers of the scale (Young et al., 2019). Since we were most interested in understanding which households experienced severe water affordability and availability, we constructed binary responses that combined *never*, *rarely* and *sometimes* into one category (0 = can afford or can locate water), and *often/always* as another category (1 = cannot afford or cannot locate water).

Water service type: To contextualize water access, we asked households about their primary water source and physical water acquisition method. Two survey questions asked - (1) “Which type of water source does your household primarily have access to?” and (2) “In which ways does the household primarily have access to this water?” The first question assesses whether households access water through a formal source, or an informal source. The second question assesses the physical infrastructure used to access this water source. During analysis of the second question, we found that all the respondents in our study sample used either “Pipe outside the household” or “Tanker of water”, therefore we create two variables - (1) water source (formal vs. informal), and (2) water service type (Tap-point i.e., pipe outside of the household vs. Tanker-truck, i.e., Tanker of water) (see Table 1).

Water expenditure: We measured household expenditure on water by asking how much money and time households spent on collecting water. We asked whether households paid for water on a monthly, weekly, or daily basis. Since 95% of our sample paid for water daily, we disaggregated the weekly and monthly responses to reflect per day cost in local currency (Kenyan Shillings). In our analysis, we converted these values to USD. To measure the time spent on water collection, we asked, “On a typical weekday, how much time was spent on water collection (round trip)?” and recorded the time spent in minutes.

Government water assistance: To secure water for Nairobi residents and the urban poor, Nairobi Metropolitan Services (NMS) deployed 22 water bowsers/trucks to reach informal settlements beginning in early 2020 (Omulo, 2021). In April 2020, following the lockdowns, some residents in Mukuru settlements benefitted from water assistance from NMS. This assistance was available intermittently on a first-come, first-served basis and was not need-based (Kimatu, 2021). To determine whether our sampled households received any free water assistance from NMS, we asked, “Since April, has your household received any free water help from the government?” with single answer responses - yes and no.

Hygiene practices: We analyzed four hygiene practices, which included inability to wash hands, body, and/or clothes, and use or drink clean water. We used the following four questions from the administered HWISE scale to measure household hygiene practices: (1) In the last 4 weeks, how frequently have you or anyone in your household had to go without washing hands after dirty activities (e.g., defecating or changing diapers, cleaning animal dung) because of problems with water?; (2) In the last 4 weeks, how frequently have you or anyone in your household

had to go without washing their body because of problems with water (e.g., not enough water, dirty, unsafe)?; (3) In the last 4 weeks, how frequently has there not been enough water in the household to wash clothes?; (4) In the last 4 weeks, how frequently have you or anyone in your household used/drank water that looked, tasted, and/or smelled bad? In the second question, we use the term “washing body” rather than narrower terms like “showering” or “bathing” because it encompasses many potential modes of washing up, including using wet towels and/or small buckets, as is common in the informal settlements. We pooled these items into a hygiene practice score, where each item had Likert responses scored from 0 to 3 where 0 = never (0 times), 1 = rarely (1–2 times), 2 = sometimes (3–10 times), 3 = often (11–20 times) or always (>20 times). We ran Principal Component Analysis (PCA) on the HWISE variables, which clustered around the four hygiene variables as one component. This clustering of the hygiene variables around one component provided further justification to combine the hygiene variables into one score. Scores for the four questions were summed to get a composite measure of hygiene practice, with a possible range of 0–12 for each household. To make the score intuitive for interpretation, where a higher score means higher levels of household hygiene, we subtracted each score from 12, which yielded a score ranging from 0 (lowest hygiene) to 12 (highest hygiene).

Household characteristics: We collected household characteristics as control variables, which included whether the head of household was female (vs. male), household tenure status (tenant vs. owner) and the type of housing structure (apartment building vs. shack). Although we requested monthly income information from respondents, we did not include an income variable in our analysis because more than 40% of our sample declined to respond to the question. Instead, we asked how many regular income contributors were in the household and included that variable in analysis. We also derived a household density variable (number of people per room) as another household characteristic variable.

4. Data analysis

First, we cross tabulated lockdown-induced employment and business disruptions by four household characteristics that we believe were unlikely to have changed for most respondents between the onset of the lockdown period (April 2020) and our survey: housing tenure, home type, water source, and water infrastructure. Because prior research has demonstrated that housing tenure and home type are associated with vulnerability or socioeconomic disadvantage (Gulyani et al., 2014; Joshi et al., In review), investigating lockdown period employment disruptions by household conditions can provide insight into whether subsequent water affordability and availability factors are caused by the lockdowns themselves or by endogenous, pre-existing conditions that already existed within disadvantaged households.

We then performed Pearson’s Chi² and Fisher’s Exact tests using STATA 15 to compare the differences in water affordability of households that experienced employment disruptions due to lockdowns versus households that did not experience employment disruptions. Then, we performed a logistic regression to examine which household characteristics were associated with households’ abilities to afford water.

Next, to understand the relationship of water availability and affordability to hygiene, we performed Wilcoxon Rank-Sum tests to assess the difference between median values of four hygiene practices for households that could afford water and those that could not. We also performed these Wilcoxon Rank-Sum tests for households that could locate water (availability) in the settlements and those that could not. We then conducted Two-Sample t-tests to assess the difference between mean hygiene scores for households that could afford and locate water, as compared to those that could not. Finally, we performed a multivariate linear regression to assess the relationship between hygiene scores and household water affordability, availability, water supply source, water infrastructure, government water assistance, daily cost of

water, time spent on acquiring water and a suite of demographic and household characteristics.

5. Results

In the 532 households analyzed, the average household density was 2.7 people per room (Table 2), and most households had male heads (71%, Table 3). About 96% of households used informal water sources to fulfill their water needs, with the majority of households using tap-points at road transects (79%) followed by tanker-trucks (21%) to collect water. The average time per round trip to collect water was about 19 min, and average daily expenditure on water collection was 0.36USD (36 Kenyan shillings) (Table 2).

Across the three settlements, 39% of sampled households reported having members that were forced to stop their own business due to lockdowns, and 96% of households had members that were forced to work less (either for themselves or for an employer). Only 22% of households reported having members that found alternate employment during the lockdowns in the case of work reduction or loss because of the COVID-19 pandemic lockdowns (Table 3). Around two thirds of households indicated frequently (>11 times since April) lacking money to buy water. Around 62% of households indicated that they received water assistance from the government at least once between April and June 2020.

5.1. Relationship between lockdown period employment and business disruptions and household characteristics

To begin, we investigated the relationship between lockdown-related employment outcomes and four presumably time-stable household characteristics—housing tenure, home type, and two measures of water services – to determine whether the employment and business disruptions were associated with pre-existing household-level features. We identified somewhat higher rates of work hour reduction among tenants than owners (96% of tenants experienced work hours reduction, compared with only 88% of homeowners) and somewhat lower rates of work hour reduction among those who live in shacks than apartments (95% of shack residents experienced work hours reduction, compared with 98% of apartment residents), but neither of these differences were significant according to a Fisher’s exact test ($p = .113$ and $p = .746$, respectively). Likewise, we identified insignificant differences between tenants and owners in their likelihood of having a business shut down due to lockdowns (38% of tenants, compared with 54% of owners, $p = .193$). Of the 22 respondents who did not reduce work hours, 91% received their water from informal sources, and 82% received their water from tap-points. Of those who did reduce work hours, values were similar: 96% received their water from informal sources, and 79% used tap-points. According to Chi² tests, these values were not significantly different ($p = .29$ and $p = .77$, respectively). Taken together, this lack of differences suggests that, at least in these regards, the households that experienced employment and business disruptions during the lockdowns were not fundamentally different pre-pandemic from those that did not.

Notably, we do identify significant differences between shack and

Table 2
Numerical data.

Variables	Mean	Median	SD	Range	N
Hygiene Score	7.04	7.00	3.08	0.0–12.0	532
Water Collection Time (Minutes)	18.66	15.00	24.16	0.0–150.0	532
Daily Water Expenditure (US\$)	0.36	0.20	0.26	0.0–2.0	532
No. Regular Income Contributors	1.17	1.00	0.39	1.0–3.0	532
Household Density (People per Room)	2.71	3.00	1.44	0.33–11.0	532

Table 3
Categorical data.

Variable	Levels	N	%
Forced to Stop Business	Yes	206	39
	No	157	30
	Does not apply	169	32
Forced to Work Less	Yes	509	96
	No	22	4
	Does not apply	1	0
Found Alternate Employment	Yes	116	22
	No	379	71
	Does not apply	37	7
Water Affordability (since April lockdowns)	Can afford	186	35
	Cannot afford	346	65
Water Availability (since April lockdowns)	Can locate	249	47
	Cannot locate	283	53
Water Affordability (past 4 weeks, June)	Can afford	406	76
	Cannot afford	126	24
Water Availability (past 4 weeks, June)	Can locate	416	78
	Cannot locate	116	22
Water Source	Informal Water Vendor	508	96
	Formal Water Vendor	24	4
Water Infrastructure	Tap-point outside yard	422	79
	Tanker-truck	110	21
Government Water Assistance	Yes	328	62
	No	204	38
Housing Tenure Status	Tenant	508	96
	Owner	24	4
Household Head	Female	157	30
	Male	375	70
House Type	Apartment	55	10
	Shack	477	90
Settlement	Mukuru Kwa Rueben	177	33
	Mukuru Kwa Njenga	139	26
	Mukuru Viwandani	216	41

apartment dwellers in the “business shutdown” question: business shutdowns were higher among shack residents than apartment residents (31% and 16%, respectively, $p = .015$). Interestingly, this difference in business shutdowns was driven in part by higher rates of business self-ownership among shack residents than apartment residents: only 30% of shack residents selected “does not apply” in response to the question about having their own business closed during lockdowns, compared with 47% of apartment residents. These differences in employment rates and business shutdowns across housing types suggest that there existed differences between business owners and non-business owners prior to the lockdowns. However, the direction of the relationship is counter to what we would have predicted, since we expected business ownership and apartment residency to be associated with higher socioeconomic status and lower levels of vulnerability than paid work and shack residency. We therefore would expect that in our subsequent analyses, any endogenous associations between economic security and subsequent income loss might, if anything, lead to an overly modest estimation of linkages between economic disruptions and water insecurity. In the following section, we show how employment and business disruptions during the lockdowns were related to household ability to afford water.

5.2. Lockdown-induced employment and business disruptions and household ability to afford water

To analyze the first of our main research questions, we compared water affordability in the context of household businesses shutting down during lockdowns. Among those households that owned businesses, differences in their ability to afford water were marginal: 60% of households that experienced business loss reported that they frequently could not afford water in recent months, compared with 57% of households that did not experience business loss (Table 3, Fig. 2). In comparison, households that did not own businesses reported much lower rates of water affordability, with 79% reporting that they frequently could not afford to buy water. The difference in water

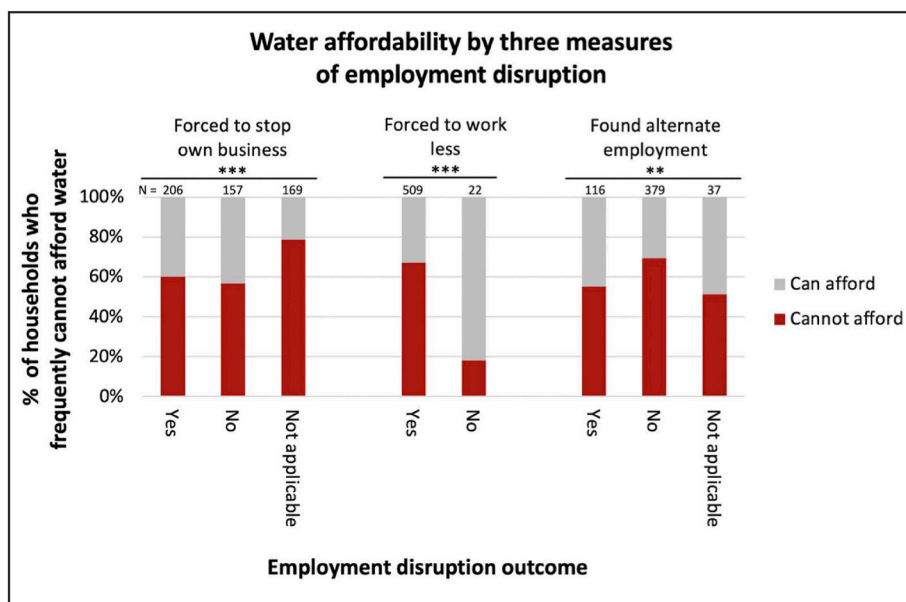


Fig. 2. Water affordability by three measures of household employment disruption during the April–June 2020 COVID lockdowns.

[Can afford = household members lacked the money needed to buy water 10 or fewer times in the past four weeks; Cannot afford = household members lacked money for water 11 or more times (since April lockdowns). “Not applicable” responses for “forced to stop own business” pertain to households that do not own a business. “Not applicable” responses for “found alternate employment” could pertain to households whose members were not in the labor market, homemakers, or didn’t experience job loss] Asterisks identify significant differences across groups according to a Pearson’s Chi2 test or a Fisher’s Exact test: ***p < .001, **p < .01, *p < .05.

affordability across these three groups was statistically significant according to a Pearson’s Chi² test (X² [2, N = 532] = 20.81, p < .001).

Next, we compared water affordability for households whose members did and did not experience a reduction in work hours during the lockdowns. The differences were staggering, with 67% of households that experienced a reduction in work reporting that they frequently could not afford water during April 2020. Only 18% of households that did not experience a reduction in work frequently could not afford water (Table 3, Fig. 2). This difference in water affordability was statistically significant according to a Fisher’s Exact test (p < .001).

We then compared water affordability for households that had members who found alternate employment during the lockdowns versus those that did not. The ability to secure alternate employment emerged as a strong predictor of ability to afford water: 55% of households who successfully found alternate employment reported that they frequently could not afford water, compared with 69% of households whose members could not find alternate employment and 51% of households for whom this question was not applicable (X² [2, N = 532] = 11.18, p = .004).

To investigate other factors associated with water affordability since the April lockdowns, we performed a binary logistic regression analysis to assess the association between water affordability, employment disruptions, and a suite of independent variables (Table 4). Households who owned a business and were not forced to stop it during the lockdowns had 3.9 times higher odds of being able to afford water than those that did not own a business (OR for “Does not apply” = 0.26 (Table 4), 1/0.26 = 3.9, p < .001). Households whose members were forced to work less during the lockdowns had 12.5 times lower odds of being able to afford water than those households whose members did not experience a work reduction (OR = 0.08 i.e., 1/0.08 = 12.5, p < .001). Households whose members found alternate employment during the lockdowns had 1.92 times higher odds of being able to afford water than households whose members were unable to find alternate employment (p = .008). Further, a household had 4.3 times greater odds of affording water if their primary water supply was through a tap-point in the settlements as opposed to a tanker-truck (p < .001). Household characteristics played an important role, where every unit increase in household density was associated with an 18% reduction in household ability to afford water (OR = 0.82 i.e., 1–0.82*100, p = .011).

Table 4

Logistic regression with household ability to afford water as the dependent variable.

HH ability to afford water ^a	Odds Ratio	St. Error	p-value	[95% Conf Interval]	
Stopped Business ^a (ref = no)					
Yes	.76	.19	.271	.47	1.24
Does not apply	.26***	.08	.000	.15	.46
Reduced Work Hours ^a (ref = no)					
Yes	.08***	.05	.000	.02	.27
Alternate employment ^a (ref = no)					
Yes	1.92***	.48	.009	1.17	3.12
Does not apply	.79	.34	.586	.34	1.87
Infrastructure: Tap point (ref = tanker-truck)					
Yes	4.26***	1.42	.000	2.22	8.20
Water Source: Informal (ref = formal)					
Yes	.65	.33	.389	.24	1.75
Daily Water Expenditure (US \$)					
Yes	1.08	.43	.84	.49	2.36
Water Collection Time ^b					
Yes	1.02	.11	.821	.83	1.26
Govt. Water Assistance					
Yes	1.14	.25	.552	.74	1.75
Household Density					
Yes	.82**	.07	.011	.69	.96
No. of Income Contributors					
Yes	1.49	.39	.126	.89	2.49
Housing Tenure: Renter (ref = homeowner)					
Yes	.58	.29	.272	.22	1.53
House Type: Apartment (ref = shack)					
Yes	1.78	.59	.08	.93	3.39
Household Head: Male (ref = female)					
Yes	.79	.19	.312	.49	1.25
Settlement (ref = Mukuru Kwa Njenga)					
Yes	1.38	.38	.251	.79	2.37
Yes	1.58	.45	.106	.91	2.76
Constant					
Yes	4.33	4.5	.158	.57	33.08
Mean dependent var					
Yes	0.350	SD dependent var		0.477	
Pseudo r-squared					
Yes	0.156	Number of obs.		532	
Chi-square					
Yes	107.694	Prob > chi2		0.000	
Akaike crit. (AIC)					
Yes	616.941	Bayesian crit. (BIC)		693.921	

***p < .001, **p < .01, *p < .05.

^a Data reflect water affordability and employment conditions since the onset of the April lockdowns.

^b Water collection time was measured in minutes and ranked during analysis as follows – 0 min = 1; Up to 15 min = 2; Up to 30 min = 3; Up to 1 h = 4; Up to 2 h = 5; 2+ hours = 6.

5.3. Water affordability, availability, and hygiene practices

Next, we investigated whether household water affordability and availability during the lockdowns were related to hygiene practices. Fig. 3 shows households' ability to maintain four hygiene practices - hand washing, body washing, clothes washing, and using/drinking clean water - by households' self-reported ability to afford water. "Cannot afford" includes those households who indicated that they "often" or "always" lacked the money to buy water in June of 2020, whereas "can afford" includes those households who indicated that they "never," "rarely," or "sometimes" lacked the money to buy water. Rates of reported inability to wash hands, wash body, wash clothes and drink/use clean water were significantly greater for households that could not afford water than for households that could ($Z = 5.6$; 5.7 ; 5.3 ; 7.0 respectively, according to Wilcoxon Rank Sum tests, with all p -values $<.001$).

Similarly, Fig. 3 also shows the distribution of households' ability to maintain four hygiene practices - hand washing, body washing, clothes washing and, using/drinking clean water - by their self-reported ability to locate water. "Cannot locate" includes those households who indicated that there was "often" or "always" nowhere to buy water in June of 2020, whereas "can locate" includes those households who indicated that there was "never," "rarely," or "sometimes" nowhere to buy water. Rates of reported inability to wash hands, wash body, wash clothes and drink/use clean water were significantly greater for households that could not find water than for households that could ($Z = 6.1$; 6.9 ; 6.9 ;

7.3 respectively, according to Wilcoxon Rank Sum tests, with all p -values $<.001$).

Next, we combined the four hygiene practice variables into a hygiene score that ranged from 0 to 12, where a low score reflects a low hygiene level. Fig. 4 compares hygiene scores for households across water affordability and availability. According to a two-sample t -test, the hygiene scores of households that could not afford water ($M = 5.2$, $SD = 2.7$) were significantly lower than for households that could afford water ($M = 7.6$, $SD = 2.9$, $p < .001$). Similarly, hygiene scores of households that could not locate water ($M = 4.8$, $SD = 2.6$) were significantly lower than for households that could locate water to buy ($M = 7.7$, $SD = 2.9$, $p < .001$).

To identify household variables that relate to levels of household hygiene, we performed a multivariate linear regression with the household hygiene score as the dependent variable and water affordability, water availability, and other household characteristics as independent variables (Table 5). Households that could frequently afford water had hygiene scores 1.88 points higher than households that could not afford water, holding all other variables constant ($p < .001$). Similarly, there was a significant positive association between water availability and hygiene scores, whereby households that were frequently able to locate water during the lockdowns had a hygiene score 1.84 points higher than households that were unable to locate water in the settlements ($p < .001$). Thus, households that could afford water and locate water were able to maintain higher levels of hygiene than households that were unable to afford and access water.

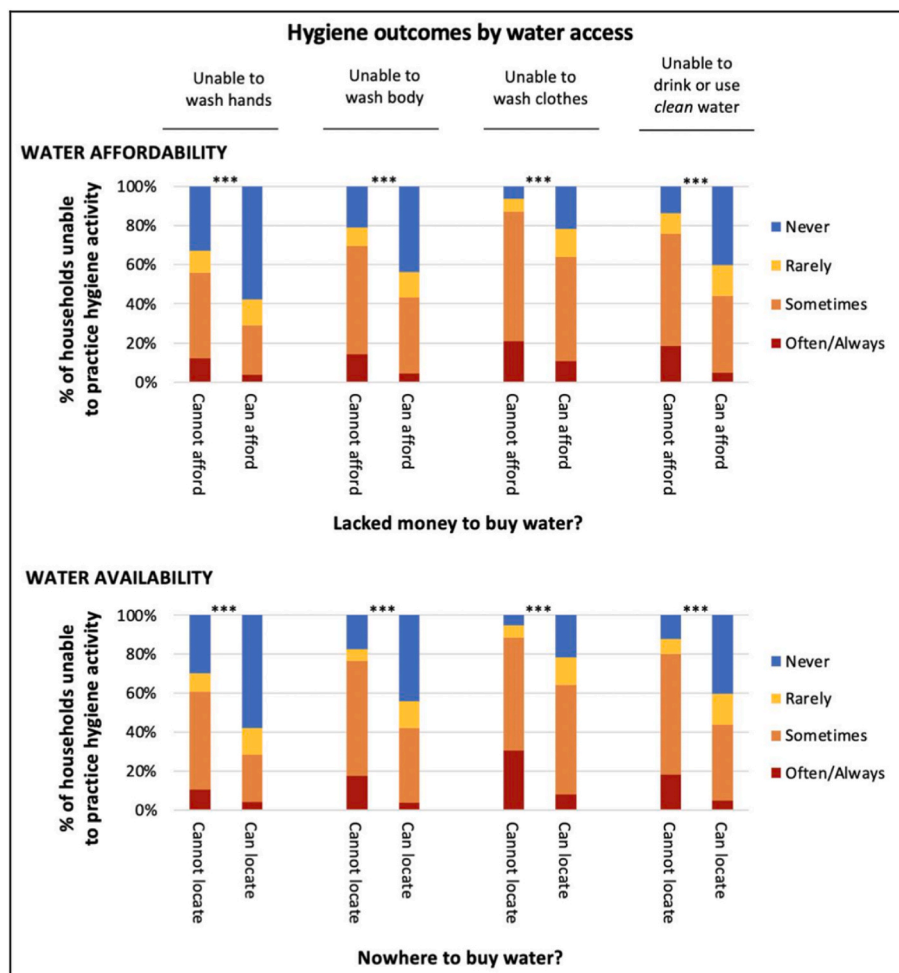


Fig. 3. Hygiene practices by households' described ability to afford and locate water in June 2020. [Never = 0 times/4 weeks, Rarely = 1–2 times, Sometimes = 3–10 times, Often/Always = >11 times] $N = 125$ for "cannot afford," 406 for "can afford," 115 for "cannot locate," and 416 for "can locate." Asterisks identify significant differences across groups according to a Wilcoxon Rank Sum test: $***p < .001$, $**p < .01$, $*p < .05$.

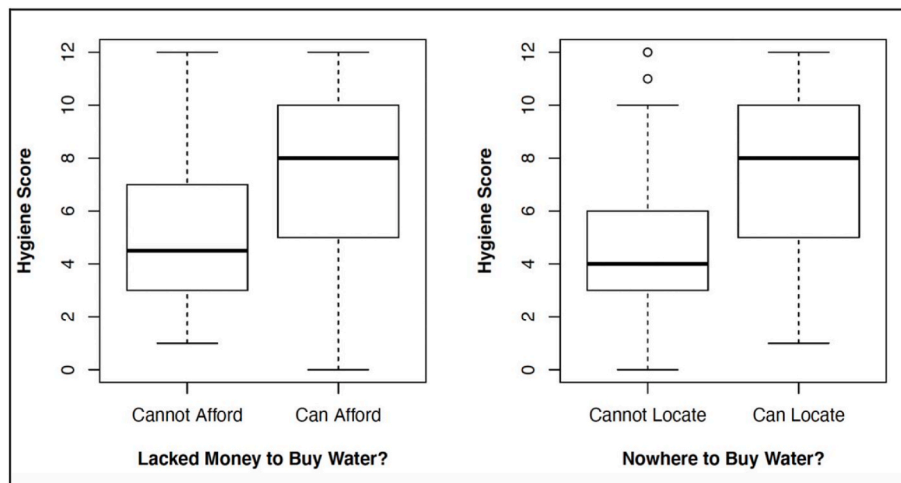


Fig. 4. Household hygiene scores (0–12) by reported affordability and availability of water in June 2020. Heavy lines represent median scores, boxes represent interquartile ranges (IQRs), and whisker lengths depict the furthest observation within 1.5 IQRs of the end of the box. N = 125 for “cannot afford,” 406 for “can afford,” 115 for “cannot locate,” and 416 for “can locate.”

Table 5
Multivariate linear regression with hygiene score as the dependent variable.

Hygiene Score	Coef.	St. Error	p-value	[95% Conf Interval]	
Could Afford Water ^a (ref = no)	1.88***	.28	.000	1.34	2.42
Could Locate Water ^a (ref = no)	1.84***	.29	.000	1.28	2.4
Water Source: Informal (ref = formal)	-.53	.55	.341	-1.61	.56
Water Infrastructure: Tap point (ref = tanker-truck)	1.33***	.29	.000	.79	1.91
Daily Water Expenditure (US\$)	-.60	.46	.192	-1.51	.30
Water Collection Time ^b	-.41***	.12	.000	-.64	-.18
Govt. Water Assistance	.15	.24	.541	-.32	.60
Housing Tenure: Renter (ref = homeowner)	-.99	.56	.077	-2.08	.11
House Type: Apartment (ref = shack)	1.29***	.37	.001	.55	2.02
No. of Income Contributors	.39	.30	.201	-.21	.98
Household Density	-.27***	.08	.001	-.43	-.11
Household Head: Male (ref = female)	-.06	.26	.833	-.57	.46
Settlement (ref = Mukuru Kwa Njenga)					
Viwandani	.92***	.29	.002	.33	1.51
Kwa Rueben	1.12***	.30	.000	.53	1.71
Constant	4.95	.96	.000	3.07	6.83
Mean dependent var	7.032	SD dependent var		3.080	
R-squared	0.323	Number of obs.		532	
F-test	17.612	Prob > F		0.000	
Akaike crit. (AIC)	2528.134	Bayesian crit. (BIC)		2592.283	

***p < .001, **p < .01, *p < .05.

^a Data reflect affordability and availability of water during the four-week period prior to taking the survey.

^b Water collection time was measured in minutes and ranked during analysis as follows – 0 min = 1; Up to 15 min = 2; Up to 30 min = 3; Up to 1 h = 4; Up to 2 h = 5; 2+ hours = 6.

Household hygiene score was also significantly associated with access to physical water infrastructures. Households that had access to tap-points had hygiene scores 1.33 points higher than those that primarily accessed water through tanker-trucks (p < .001). Daily time expenditure on roundtrip water collection was negatively associated with hygiene practices, where a one unit increase in collection time was associated with a 0.41-point decrease in hygiene levels (p = .001).

Households that lived in apartments had hygiene scores 1.29 points

higher than those that lived in shacks (p = .001). Similarly, households with higher household density had lower hygiene scores, whereby with every one unit increase in household density, hygiene levels decreased by 0.27 points (p = .001). These results reveal important associations between household characteristics and the ability to maintain good hygiene practices. Although all three study sites are informal, their hygiene scores differ. Households living in Mukuru Viwandani and Mukuru Kwa Rueben settlements had hygiene scores that were 0.92 and 1.12 points higher, respectively, than in Mukuru Kwa Njenga settlement (p = .001 and p < .001, respectively). In comparison, type of water source, daily expenditure on water, household tenure status, number of regular income contributors, gender of household head, and receipt of government water assistance were not significantly associated with hygiene practices.

6. Discussion

This study documents household access to water and hygiene practices in the context of employment and business loss during the pandemic. We examine two relationships: (1) the association between COVID-19 induced employment and business disruptions and household water affordability, and (2) the relationship between water access (affordability and availability) and household hygiene practices. Our results show that during the COVID-19 lockdowns, informal settlements faced a compounding tragedy of employment and business loss, reduced water access, and lower levels of hygiene, at a time when hand washing was identified as one of the most important elements of reducing the disease burden. This has implications for addressing water insecurity challenges in informal settlements, where the fragile water provision systems have failed to meet all residents' water needs since before the pandemic (Crow and Odaba, 2009; Nilsson and Kaijser, 2009).

A staggering 96% of sampled households were forced to reduce work hours during the lockdowns, and those who were forced to reduce work had 92% lower odds of being able to afford water than households who did not experience work reductions. A staggering 96% of sampled households were forced to reduce work hours during the lockdowns, and those who were forced to reduce work had 92% lower odds of being able to afford water than households who did not experience work reductions. These findings add to the growing literature showing the increased vulnerability of low-income households to socio-economic losses during the pandemic (Josephson et al., 2021). In addition, the paper contributes to evidence that low-income populations are particularly vulnerable to reductions in earnings, and face difficulties

affording basic needs such as food, water, sanitation (Devereux et al., 2020; Stoler et al., 2021).

Prior studies show that early lockdowns had a detrimental impact on small enterprises worldwide (Balde et al., 2020; Chirisa et al., 2020; Sunday, 2020). Our study affirms this finding, and adds new insights in the context of informal settlements. In our study sites, of the 68% of households who ran a small enterprise, over half had to shut down their business during the lockdowns. Despite our expectation that business disruptions would detrimentally affect households' abilities to buy water there were no significant differences in water affordability among those households who had to shut down their business as compared to those that did not have to. Instead, the non-business owner households experienced particularly low rates of water affordability, which suggests that households most dependent on wage laborers faced greater barriers to afford water than small business owners during the lockdown period. Our study therefore provides insight into the variability of the pandemic's differential impacts on households with businesses versus households dependent on wage laborers in informal settlement populations.

At the outset of the pandemic, hygiene practices such as hand washing were deemed essential to saving lives in extremely poor areas such as informal settlements (CDC, 2021; Olapeju et al., 2021). However, in our study sites, hygiene practices were not practiced evenly across the population, as households that reported being able to afford water had significantly higher hygiene scores than households that reported not being able to afford water. This finding highlights how vulnerable households are under conditions of reduced water affordability and supports the need for immediate action to provide water assistance, alcohol-based hand and surface sanitizers, and hand-washing stations in informal settlements (Loftus and Sultana, 2020; Parikh et al., 2020). Ultimately, these pandemic-era measures may also help improve long-term hand washing behaviors, thereby saving lives from other disease burdens in a post-pandemic future.

Our findings of widespread water insecurity also suggest that the water assistance effort started by NMS in Nairobi during the pandemic is insufficient in its ability to meet community needs. NMS intermittently brings free water into the settlements on a first-come, first-served basis, however, the frequency of delivery and/or geographic distribution of these efforts do not meet the needs of the entire population (Omulo, 2021). We therefore suggest that the NMS effort should be scaled up or supplemented by regular, systematic provision of targeted need-based water assistance. Community interventions may not reach all households, and as shared water stations may violate pandemic-era curfew laws and social distancing guidelines (Wasdani and Prasad, 2020). Thus, we also emphasize the need for investments in water service infrastructures at the household level, rather than solely focusing on installing community level water facilities.

Water insecurity has also been a long-standing problem for residents of informal settlements since well before COVID-19. Short-term responses to meeting the water needs of the urban poor may alleviate the current hardships. However, a long-term approach to improving water supply services in informal settlements by investing in permanent on-premises water infrastructures will be essential in improving the well-being of residents during pandemic and non-pandemic periods alike, as guided by Sustainable Development Goal 6 (Grasham et al., 2021; Wutich et al., 2021).

There are some limitations to consider when interpreting the findings of this study. First, due to the absence of pre-pandemic baseline data in our study, we were unable to attribute hardships specifically to the COVID-19 lockdowns and/or the associated employment and business disruptions. In addition, in-person data collection was not possible in 2020. Thus, we conducted household surveys remotely via phone calls, which limited the time we had to ask follow-up questions. Additionally, in our dataset, we examine self-reported affordability of water, which could be influenced by faulty recall or by differences in respondent's definitions of "affordability." For instance, households' numerous

additional budgetary demands (e.g., food, fuel, shelter) might influence respondents' perception of water affordability. Although less subjective methods of measuring water affordability exist (e.g., calculating the household's expenditure on water as a proportion of the annual income), no indicator is perfect, as each one performs differently against the criteria of validity, relevance, and global coverage of reliable data sources (Hutton, 2012). We therefore believe that self-reported affordability, alongside objective measures of cash expenditures on water, time costs, and non-monetary access (i.e., water service infrastructures), provides as robust a measure of affordability as possible in this context. Lastly, our cross-sectional study design does not account for seasonal variation in rainfall patterns that may also affect availability of water.

Future research can examine water affordability using objective measures such as a ratio of water expenditures to income (UNICEF & WHO, 2021) and take seasonal variation into account. In addition, comparing the early lockdown periods (April–June) to later periods in 2020 and 2021 would be useful to document the continuing impacts of the pandemic on households' water affordability in informal settlements. Key lines of inquiry can investigate the coping strategies that may have been adopted over time to maintain hygiene practices, and the role of supporting interventions to alleviate water insecurity. This research could also include qualitative inquiries such as in-depth interviews and participant observation, which we were unable to incorporate in our study due to data collection limitations during the early pandemic period. In-depth interviews can supplement household survey findings on, for instance, why some households could still afford water despite a disruption in employment. Addressing these additional research questions can give insight into how the government, civil society, and donor organizations can best target assistance.

7. Conclusion

This study's unique early-pandemic data shed light on water insecurity and pandemic-era hygiene in an informal settlement context. We use these data to analyze relationships between employment and business loss, water access and hygiene practices among one of the world's most vulnerable populations, at a time when these vulnerabilities were hardest to measure due to the lockdowns. The pandemic introduced several shocks to the already stressed informal settlements of Nairobi. Our findings suggest that challenges affording water during the pandemic were associated with a combination of factors, including lockdown-related employment and business disruptions. In turn, the inability to afford water was associated with reduced ability to practice hygiene behaviors including hand washing. Pandemic-era water insecurity may have placed informal settlement populations – and particularly those households who experienced employment shocks – at an elevated risk of disease contraction. Given these findings, we argue for more targeted investments in permanent water supply infrastructures designed to be affordable and accessible to the urban poor. In addition, consistent interventions to improve and remove barriers to hygiene behavior should be a public health priority.

CRedit author statement

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