

HOUSING AND WATER INSECURITY IN NAIROBI'S INFORMAL SETTLEMENTS

by

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DEDICATION

Dedicated to my parents Smita and Nitin Joshi, who have worked tirelessly, and sacrificed their own pursuits to support my endeavors.

TABLE OF CONTENTS

LIST OF TABLES.....	9
LIST OF FIGURES.....	10
ABSTRACT.....	11
CHAPTER 1: INTRODUCTION.....	13
1.1 Statement of Problem.....	13
1.2 Background.....	17
1.3 Organization of Dissertation.....	21
CHAPTER 2: CONCLUSION.....	23
WORKS CITED.....	26
APPENDIX A: Water insecurity, housing tenure, and the role of informal water services in Nairobi’s slum settlements.....	32
A.1 Abstract.....	33
A.2 Highlights.....	34
A.3 Introduction.....	34
A.4 Housing and Water Security in Slum Settlements.....	38
A.4.1 Tenure security and informal water services.....	39
A.4.2 Water security and insecurity.....	41
A.5 Research Setting.....	43
A.6 Data and Methodology.....	48
A.6.1 Data collection.....	48
A.6.2 Water insecurity scores.....	51
A.6.3 House tenure status, water services, expenditures, and household characteristics.....	52
A.7 Data Analysis.....	55
A.8 Results.....	56
A.8.1 Access to water services and household tenure status.....	56
A.8.2 Cash expenditure and collection time from formal versus informal services.....	58
A.8.3 Household tenure status and water insecurity.....	59
A.8.4 Correlates of water insecurity in Mukuru settlements.....	60
A.9 Housing Tenure, Water Security and Pathways Forward.....	64
A.10 Acknowledgements.....	71
A.11 References.....	71

APPENDIX B: COVID-19 lockdowns: Employment and business disruptions, water access and hygiene practices in Nairobi’s informal settlements	87
B.1 Abstract.....	88
B.2 Highlights.....	89
B.3 Introduction.....	89
B.4 Methods.....	92
B.4.1 Research context.....	92
B.4.2 Study design and sampling.....	95
B.4.3 Data collection procedures.....	96
B.4.4 Ethical adherence.....	96
B.5 Measures.....	96
B.6 Data Analysis.....	100
B.7 Results.....	101
B.7.1 Relationship between lockdown period employment and business disruptions and household characteristics.....	104
B.7.2 Lockdown-induced employment and business disruptions and household ability to afford water.....	105
B.7.3 Water affordability, availability, and hygiene practices.....	110
B.8 Discussion.....	116
B.9 Conclusion.....	120
B.10. Acknowledgements.....	121
B. 11 References.....	121
APPENDIX C: Where do slum households move after evictions: A study of living status of households pre- and post-evictions in Nairobi’s informal settlements	130
C.1 Abstract.....	130
C.2 Introduction.....	131
C.3 Data Collection.....	136
C.4 Research Setting.....	138
C.5 Nature of Ongoing Evictions and Household Living Status.....	140
C.6. Change in Household Characteristics: Pre and Post Evictions.....	141
C.6.1Changes in housing tenure and rent prices through 2020-2022.....	142
C.7. Change in Water Access Pre and Post Evictions.....	146
C.7.1 Water services.....	146
C.7.2 Water cash and time expenditures.....	147
C.7.3 Household water insecurity experience (HWISE).....	149
C.8. Post-Eviction Losses, Aid and Movement of Households.....	151
C.8.1 Self-reported eviction reasons, notice of evictions, and humanitarian aid.....	151
C.8.2 Movement post-evictions.....	153
C.9. Discussion.....	155

C.10. References.....159

LIST OF TABLES

Table A.1.....	47
Table A.2.....	54
Table A.3.....	54
Table A.4.....	57
Table A.5.....	61
Table B.1.....	94
Table B.2.....	102
Table B.3.....	102
Table B.4.....	108
Table B.5.....	114
Table C.1.....	144
Table C.2.....	144
Table C.3.....	147
Table C.4.....	152
Table C.5.....	153

LIST OF FIGURES

Figure A.1.....	60
Figure B.1.....	93
Figure B.2.....	107
Figure B.3.....	112
Figure B.4.....	113
Figure C.1.....	139
Figure C.2.....	143
Figure C.3.....	146
Figure C.4.....	148
Figure C.5.....	149
Figure C.6.....	151
Figure C.7.....	154

ABSTRACT

Presently, about one billion people reside in informal and slum settlements around the world, creating an ongoing development challenge. Slum settlements are the most deprived and excluded type of informal settlements, characterized by large agglomerations of dilapidated housing located in hazardous urban land, lacking formal supply of basic services such as housing, water, sanitation, and so on. (Habitat, 2015). Informal settlements grapple with unique contextual challenges of having settled on speculated land for generations, with limited power over its use, due to lack of land tenure security. This lack of tenure security poses an additional challenge for municipal and national governments in providing basic services (Gulyani et al., 2018). In particular, safe and affordable access to water for slum residents remains unmet, as informal settlements often lack municipal water supply coverage and rely on small-scale informal water services (Garrick et al., 2019; WHO, 2019). It is argued that informal settlement residents' perceptions of land tenure security also influence their housing investment behaviors, where only a small percentage of them are able to invest and own houses (Gulyani et al., 2018; Nakamura, 2016; Van Gelder, 2010). Furthermore, lack of home ownership titles hinders the capacity of tenants to invest in permanent water, sanitation, and electricity connections due to fear of evictions (De Soto, 1989; Payne, 2002; Satterthwaite, 2005). In addition, climate change and rapid urbanization compound these challenges by placing additional burdens on affordability and accessibility of water for slum dwellers, especially the tenants in these settlements.

This dissertation is an investigation into the linkages between informal urbanization and household water security. In doing so, I conducted research in three settlements in the city of Nairobi through the years 2018-2022. My investigation in the settlements of Mukuru Kwa Njenga, Kwa Reuben, and Viwandani began in the summer of 2018 and summer of 2019, and continued

in 2020 during a global pandemic, and during the years 2021 and 2022, when there were several evictions and demolitions in the settlements, in addition to an ongoing pandemic. The dissertation took a mixed-methods approach, and two modalities - in-person and remote (over phone) using semi-structured interviews, focus group discussions, stakeholder workshops, and phone surveys.

The first component of the dissertation examines the relationships between housing tenure (tenancy vs. homeownership), access to water service types (formal vs. informal; tap-points vs. tanker trucks), and household water insecurity levels. I identified a strong relationship between tenancy and water insecurity levels, and household access to formal vs. informal water services. These findings have important implications for development interventions that singularly focus on water infrastructures, whereas I show the importance of addressing housing tenure injustice in slums to alleviate water insecurity and access.

The second study investigated the relationships between pandemic related lockdown induced employment and business disruptions, water affordability and accessibility, and hygiene practices such as hand washing among households. I found that the study sites which already struggled with water accessibility, lockdown-era employment and business disruptions were associated with additional water-related hardships, and lower hygiene levels.

In the final study, I investigated the movement of the study sample after eviction and demolition events during 2021 and early 2022. I found that, of the households who were evicted for redevelopment purposes, a majority of them came back and resettled in the same settlements from which they were evicted, or a minority of them moved to nearby informal areas. I show that urban renewal projects that evict informal settlement households lead to increasing the population density of the existing informal areas. Overall, this dissertation sheds light on larger development challenges of rapid urbanization, water security, and exacerbating inequality in the city of Nairobi.

CHAPTER 1: INTRODUCTION

1.1 Statement of Problem

The world is rapidly urbanizing, and more than half the world's population is now living in cities, and that share is projected to rise to 60 per cent by 2030 (United Nations, 2018). This rapid urbanization is also resulting in a growing number of slum and informal settlement dwellers, with governments being unable to provide adequate infrastructure and services to these populations. In African cities, over half of the urban population (61.7%) lives in informal settlements (Habitat, 2013), where basic services such as water, sanitation, electricity, and secure housing are lacking. In terms of water needs, an estimated 80% of these populations resort to informal water providers such as street vendors, water resellers, kiosks and water tankers (Dardenne, 2006; Kariuki & Schwartz, 2005). Moreover, informal settlements lack land and housing tenure security, making them highly vulnerable to forced evictions (Golubchikov & Badyina, 2012).

In this dissertation, I address three major development challenges plaguing informal settlements and cities in developing countries - lack of land and housing tenure for informal settlements, forced evictions, and proliferation of informal water services which are expensive, unreliable, and poor in quality. In doing so, I draw on my data collection conducted in the settlements of Mukuru Kwa Njenga, Kwa Reuben, and Viwandani, (referred as Mukuru settlements henceforth) - one of the largest of over 150 informal settlements in Nairobi. The project is use-inspired as its questions are drawn from the needs of the Special Planning Area (SPA) that is being implemented in the settlements by the Nairobi City County to improve basic services in the area.

In the summer of 2018 and 2019 I examined how the different types of formal, informal, and hybrid water services operated in the settlements, and their relationship with household water insecurity. This was important because Mukuru settlements were declared SPA in 2017, and as part of the SPA, the questions that city planners were asking were - how do they redevelop the settlements' water supply systems, and how to deal with informal water vendors? Can informal water vendors become partners in the renovation endeavor? And, how can urban planners solve the water security issues in the settlements using a participatory approach. As an observer in these conversations, I was asked if I could investigate some of these questions. I gladly took this up as it opened up an opportunity for me to have my research inform decision making.

As I spent more time in the settlements understanding the operations of informal water vendors, conducting interviews with government officials, focus groups with informal water providers, and household surveys with the community members, it was evident that if the settlements were to be redeveloped and its water systems renovated, land disputes had to be resolved and housing tenure security was important to achieve (I elaborate more on this in APPENDIX A). If households had secure land and housing tenure without the fear of evictions, they showed willingness to apply for municipal water connections, and invest in other infrastructural improvements. This could open an opportunity for urban planners to partner with households and install municipal water infrastructures. However, at the existing stage with insecure land and housing tenure, a majority of households had no option but to rely on informal water vendors, as they could not afford the long-term investment of acquiring municipal water connections, due to the fear of evictions. The three big development challenges were evident at this micro-scale. The poor households residing in these settlements for 20+ years were trapped in insecurity cycles - lack of land and housing tenure contributed to a constant fear of evictions and

impermanence. This further pushed households to rely on temporary informal vendors - these vendors, though making access to water possible, sold water at prices 4 times higher than municipal water tariffs. To test these observations, in my first study, I asked three questions -

- (1) What is the relationship between housing tenure status and household water insecurity?
- (2) What role does household tenure status play in access to different water service types among households?
- (3) How does access to different water service types, and cash and time expenditures relate to household water insecurity?

In APPENDIX A, I report on the findings from analysis of these questions and discuss the importance of housing tenure security i.e., expanding homeownership among slum dwellers to alleviate water insecurity. To my best knowledge, there is no empirical study identifying the key link between housing tenure, access to types of water services and household water insecurity levels in slum settlements. I also fill in a gap in the evolving literature on urban water security by measuring water insecurity using the cross-culturally validated Household Water Insecurity Experience (HWISE) scale which has not been tested in the context of slum settlements. The scale accounts for various aspects of insecurity such as access, quality, quantity, safety, hygiene, psychological distress and social exclusion. In communicating these results to the Nairobi city County, I wrote a policy brief emphasizing the need to tackle housing tenure injustice in the settlements as a pathway to renovating Mukuru's water services.

In March 2020, a global pandemic furthered this quest on addressing the three big development challenges – how does a global pandemic induce new stressors in the already struggling households in Mukuru settlements? From observations worldwide, it was evident that the pandemic exposed chronic gaps in water supply and sanitation services in low-income areas

across the world. Already more than 2.2 billion people lacked access to adequate water and did not have the option of practicing regular handwashing (Anim & Ofori-Asenso, 2020; Loftus & Sultana, 2020), which was a hygiene practice deemed crucial in the beginning of 2020. This crisis was exacerbated by the efforts to stop the spread of COVID-19 and related economic impacts have affected 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). Owing to this, I investigated the status of employment, water accessibility and affordability, and hygiene practices in Mukuru settlements using phone surveys. In doing so, I asked:

- (1) What was the relationship between employment and business disruptions during the lockdown period (April - June 2020) and household ability to afford water?
- (2) What was the relationship between water availability, affordability, and hygiene practices during the lockdowns?

In APPENDIX B, I report on the findings from analysis of these questions and discuss the implications the pandemic has had on a fundamental need, i.e., water. This study highlights the 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. This study contributes to the new but growing literature on the impacts of the pandemic on basic services among the urban poor. Specifically, the study sheds light on the status of employment, water access, and hygiene practice, empirically, at a time when collecting such data was near impossible due to travel restrictions. This unique dataset highlights the vulnerabilities of one of the most marginalized populations, and their basic needs curtailed during the lockdowns.

One of the ongoing themes throughout my inquiry was that Mukuru settlements were viewed as an ‘eyesore’ by the government officials. This came up multiple times during interviews with government officials. While there was a strong commitment to improve basic services in the settlements, and resolve land disputes to give secure land titles to people, the commitments were often weighed against other redevelopment projects such as internationally funded roads and clean streets that would attract foreign capital. As such, part of the rapid urbanization issue is that cities in the developing countries compete for acquiring foreign capital to make their city ‘world class’, and ‘smart’, in which informal settlements don’t seem to fit the fabric (Huchzermeyer, 2011). Therefore, the final study investigates the hardships households in Mukuru settlements faced throughout the years 2020-22 due to the various eviction drives. In particular, this study investigates the two types of ongoing evictions and demolitions in the settlements carried out due to urban redevelopment projects. The study shows that even though slum settlements are seen as an eyesore in the rapidly urbanizing cities, evictions and demolitions do not serve the purpose of “getting rid” of this so-called eyesore. Rather, post-evictions, the majority of evicted households in our study sample moved within the demolished settlements, or to other informal areas in Nairobi.

In APPENDIX C, I report on the findings from analysis of the following questions:

- (1) What were the changes in living conditions of households after they were evicted?
- (2) After the evictions, where did the households move and why?

1.2 Background

To investigate development challenges of informal urbanization, I draw on bodies of scholarship on water security and capabilities approach, informal water provision, slum upgrading and tenure security, and forced evictions and right to adequate housing.

Water scarcity plays an important role in determining water security of populations (Mekonnen & Hoekstra, 2016; Rijsberman, 2006). It is predicted that water scarcity might increase in the future due to climate change, which will impact water management, distribution, and security in urban centers (e.g., Cape Town). Research also shows that contemporary shortages of clean and sufficient water among urban poor households has more to do with unequal distribution rather than scarcity of water per se (Anand, 2011; Meehan, 2014; Peloso & Morinville, 2014; Ranganathan, 2014). Therefore, water supply for many large African cities will be stressed as increased scarcity, and unequal distribution will have increased water costs passed on to the households (Cameron & Katzschner, 2017). Scholars thus focus on water security considering human dimensions of it, such as political, social, economic and institutional capacities at different spatial scales, as well as environmental dimensions such as environmental change (Bakker, 2012; Bakker & Morinville, 2013; Cook & Bakker, 2012; Gerlak et al., 2018; Jepson et al., 2017).

In this dissertation, I define water insecurity as embodied in social relations and governance processes. In the study sites, I conceptualize water insecurity as produced through processes of exclusion (Loftus, 2015) - informal settlement households' exclusion from gaining housing tenure security (homeownership) impacts their ability to access municipal water services and become water secure; in turn; this exclusion from access to municipal water services also impacts their ability to become homeowners. For instance, having access to water from municipal sources can make households' presence more legitimate, making it easier to advocate for themselves in becoming a homeowner. Given the context of the study sites, I conceptualize secure housing tenure

(i.e. homeownership) as a capability that advances human flourishing via, among other routes, access to water services, which influences households' path to water security (Nussbaum, 1999; Sen, 1999, 2014) and broader achievement of human development and justice (Sen, 2014). I elaborate on this framing in detail in APPENDIX A.

To measure water insecurity in the study sites, I use the Household Water Insecurity Experience Scale (HWISE) - a cross-culturally validated scale to measure water insecurity. (Young, Boateng, et al., 2019). I describe the scale and why I use it, its limitations and strengths in APPENDIX A and B - in the background, methods, and discussions sections of both the studies. With water access being suggested as the foremost requirement to prevent COVID-19 transmission in the beginning of the pandemic, water security has become more important than ever before. As part of APPENDIX B, I discuss in detail the literature related to water access, handwashing, COVID-19 mitigation, and the new limitations the pandemic has introduced in terms of water access.

Measuring water insecurity in informal settlements is more complex, as different water services - formal and informal, as well as physical infrastructures need to be taken into account. Therefore, I also draw on a vast literature on informal water provision around the world to conceptualize and understand water provision in the context of Mukuru settlements. In doing so, I define informal water providers as small scale, independent, networked private vendors or entrepreneurs, that are not formally recognized by the government, and in many cases operate as primary water providers for low-income households and businesses (Ahmad et al., 2003; Kariuki & Schwartz, 2005; Moran & Batley, 2004; Moretto, 2007). While the modalities of their operation vary widely, most of them supply water through tanker-trucks, kiosks, tap-points or stand posts and carrier carts (Garrick et al., 2019; Raina et al., 2019; Whittington et al., 1991). I study informal

water provision in the study sites as playing a dual role - on one hand they realize the human right to water in the absence of municipal water service, whereas on the other hand their water is expensive, unreliable, and of poor quality. This approach recognizes informal vendors as an essential part of the urban fabric, but suggests ways in which their services could be improved and better serve poor households.

Addressing the question of water insecurity in informal settlements requires asking broader questions around land and housing tenure security. This is because informal settlements lack legal sanctions from the government for the land that they have been living on, making them highly vulnerable to evictions (Ghertner, 2008; Gulyani et al., 2014; Marx et al., 2013). Lack of tenure inhibits water utilities and municipal governments ability to invest in permanent water infrastructures due to the risks of evictions, demolitions, vandalism and unpaid bills (Murthy, 2012; Sarkar, 2020). In turn, it is impossible for households to advocate for ownership over the land and houses they are tenants of, because they are unable to produce formal water, electricity, waste utility bills, as the services they use are informal in nature. Due to these challenges, Mukuru settlements were declared SPA under Kenya's Physical and Land Use Planning Act (PLUPA) to address these challenges.

In studying the relationships between tenure security, water access, water insecurity, and forced evictions, I draw on the body of literature on slum upgrading around the world. To address the challenge of urban slums, modernizing approaches gained momentum beginning in the 1950s. In sub-Saharan Africa, newly independent countries adopted policies that included both slum clearance and state led rental housing programs to support the development of rapidly urbanizing cities (Stren, 2018). Ultimately, both the strategies failed in terms of cost effectiveness and benefits to the urban poor (Huchzermeyer, 2011). By the 1980s, two approaches - slum upgrading (in-situ

improvement) and sites-and-services focused on granting secure land tenure (formalization) and providing basic services to slum residents (Croese et al., 2016). Then in the early 2000s, South American economist Hernando Desoto's compelling argument for home ownership and land titling in slums (De Soto, 2001) was received with international attention. This gave way to formalization of slums and extending land tenure through participatory slum upgrading programs (PSUP) (Croese et al., 2016). Upgrading services in slums began to be seen as a way to legitimize the presence of slum residents, with the argument that living conditions will improve with time, as people feel a sense of permanency and invest in better infrastructure (Croese et al., 2016; Nakamura, 2017). This approach gained more traction with the second United Nations (UN) Conference in Istanbul, in June 1996 (Habitat II). This conference gave birth to the Istanbul Declaration on Human Settlements, marking a significant turning point in the global policy discourse on the need to ensure "adequate shelter for all" (UN-Habitat, 2007). As part of APPENDIX A and C, I discuss in detail the literature related to slum upgrading and the right to adequate housing.

1.3. Organization of Dissertation

This dissertation is formatted per University of Arizona Graduate College guidelines as a Manuscript/Article Dissertation with three research projects described in three appendices. Following the introduction, the conclusion reflects on the key findings from all the three studies and its contribution to the field of geography. I also lay out my research plans moving forward as an assistant professor at the Anthropology and Sociology department at Kalamazoo College, and the socio-environmental challenges I plan to address in my scholarship.

Each appendix is formatted as a publishable manuscript complete with detailed introduction, background/literature review, methods, findings, and conclusions. I am the lead author for each manuscript, with my dissertation committee members, collaborators in Nairobi and the United States, and my advisor Dr. Tom Evans as co-authors. The first study was submitted in February 2021 and is currently in the second round of revisions with the journal *World Development*. It is included as Appendix A. The second study was submitted in January 2022 and is currently in the first round of revisions with the journal *Social Science and Medicine*. It is included as Appendix B. The third, and final study is written and prepared as a manuscript suitable for submission to the journal *Urban Studies*, and is included as Appendix C.

CHAPTER 2: CONCLUSION

In this dissertation, I investigated development challenges of urban water security and informal urbanization as it relates to informal settlements and informal water provision in Nairobi, Kenya. The three papers examined the issues of housing and water security in the settlements of Mukuru Kwa Njenga, Kwa Reuben, and Viwandani. The first component examined pathways to household water security (access, affordability, reliability, quality, quantity) as they connect to land and housing tenure challenges in three informal settlements in Nairobi. I employ an ecological study design using triangulation methods – 56 interviews with municipal water officials, 13 focus groups with informal water vendors and ~583 structured surveys with systematically sampled households. The survey consisted of validated scales such as the Household Water Insecurity Experience (HWISE) scale, Reduced Coping Strategy Index (rCSI) etc., that measured household socio-economic status and water security experience holistically. The results of my analysis (in review with *World Development*) suggests that household water insecurity levels are significantly positively associated with the tenure status of the households and the combinations of infrastructures they use (i.e., whether a government borehole, informal door-to-door delivery, or informal standpipes). This represents an important contribution to geography and social sciences broadly by demonstrating that improving housing tenure security, rather than just focusing on improving infrastructure, is critical to alleviating water insecurity in informal settlements.

The second component investigated how COVID-19 introduced several shocks in the already stressed water systems of my study sites. To understand the impacts of the pandemic on the sites, I conducted remote phone surveys with previously sampled households. My findings (in review with *Social Science and Medicine*), show a staggering impact on household ability to buy

water and wash hands, due to reduction in working hours during the lockdowns. This finding is important for public health interventions, as most of the informal settlement populations live ‘hand to mouth’. My work highlights this double tragedy – job loss and reduced water access at a time when water is crucial to maintain hygiene and good health. The final study, the third component, draws on another round of data collection done remotely in April 2022 to investigate the impacts of evictions on the sampled households. The paper (in preparation to be submitted to *Urban Studies*) examines household living status pre- and post-evictions from the years 2020 and 2022 (post-evictions). In addition, the paper maps the movement of households after evictions, and shows that the majority of the evicted households resettled back into the three informal settlements and nearby informal areas. This study contributes to the field of urban geography by mapping the movement of households to show the movement patterns of the urban poor after evictions and demolitions occurred.

In the future, as a human-environment geographer, I will continue to focus my research on cities, mainly in marginalized areas such as informal and “slum” settlements because that is where most vulnerable populations live, and the absolute numbers of these populations are expected to grow dramatically by 2050. I will continue to use a broad range of qualitative, quantitative, and collaborative methods including household surveys, semi-structured interviews, focus group discussions, participatory mapping, and open-access large survey datasets in my research.

I am also developing collaborations with scientists in the midwest region to conduct local US-based research. Starting in August 2022, I will be collaborating on a climate forecast and farmer perception study with Drs. Melissa Kenney and Heidi Roop at the Institute on the Environment at University of Minnesota. In addition, I am building collaborations with Azim Premji University in Bangalore, India to conduct a study of menstrual health and sanitation among

adolescent girls in urban India. In the near future, I would like to build collaborations with community organizations in the western Michigan area and get involved in understanding water security challenges in the great lakes region, to integrate it in my teaching and research.

As an assistant professor at the Sociology and Anthropology department at Kalamazoo College, I am excited to bring my science to classroom teaching. I am excited to teach courses of research methods, international development, water and society, and African cities, and ignite young minds to become leaders in the environmental field. Having gained robust training and experience at the University of Arizona in broad human, environment, and health fields, I am equipped to conduct research and teaching that is use-inspired and driven by the needs of the society. I am excited to continue my journey as a scholar and teacher to contribute to the world in tackling socio-environmental issues that need our urgent attention today.

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**APPENDIX A: Water insecurity, housing tenure, and the role of informal water services in
Nairobi's slum settlements**

(2nd R&R round with World Development)

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A.1 Abstract

Presently, about one billion people reside in slums around the world, creating an ongoing urbanization and development challenge. Slum settlements lack tenure security, posing an additional challenge for municipal and national governments in providing basic services. In particular, safe and affordable access to water for slum residents remains unmet, as slum settlements often lack municipal water supply coverage and rely on small-scale informal water services. We examined the dynamics between housing tenure status (tenancy vs. ownership), water service types, and water insecurity among households in three slum settlements in Nairobi, Kenya. Using a cross-culturally validated 11-item Household Water Insecurity Experience (HWISE) scale, we identified a key link between housing tenure status and water insecurity, based on survey data from 556 households. We found that water insecurity in the study sites is a significant challenge because of the link between housing tenure and access to different water service types. As such, water insecurity scores among tenants were significantly higher than homeowners, and this association persists even after controlling for household characteristics. Furthermore, a higher percentage of homeowners had access to formal water services than tenants and accessing water from informal water providers was related to higher water insecurity. Our results highlight the need for development interventions in slums to consider housing tenure of residents when planning interventions to alleviate water insecurity. To meet the goal of ‘equitable water for all’ set by the United Nations Sustainable Development Goals (SDGs), governments must also take key steps to resolve housing tenure injustice and expand home ownership in slum settlements.

Keywords: water security, housing tenure, informal water services, slum settlements, Nairobi, sub-Saharan Africa

A.2 Highlights

- Tenants had higher levels of water insecurity than homeowners in the slum settlements.
- Tenants primarily used informal water services as opposed to homeowners who had better access to formal water services.
- Water and housing insecurity are linked: access to type of water services was associated with housing tenure status.
- Improving housing tenure and elevating rates of home ownership may help in alleviating water insecurity among slum households.

A.3 Introduction

Two-thirds of the world's population experiences water scarcity at least part of the year (Mekonnen & Hoekstra, 2016), yet this is likely an underestimation (Young, Boateng, et al., 2019). Even though the United Nations (UN) Millennium Development Goals (MDGs) guaranteed access to safe drinking water, more than 700 million people still lacked water access by the end of 2014 (Satterthwaite, 2016; UNICEF, 2017; World Health Organization, 2014). The UN Sustainable Development Goals (SDGs) have furthered this agenda including access, quantity, quality and affordability as key parameters for assessing household water provision (W. Jepson et al., 2017). Specifically, SDG target #6.1 aims “to achieve universal and equitable access to safe and affordable drinking water for all” (UN Water, 2018). Inclusion of the idea of ‘equity’ in this global call draws attention to both social and economic differences that inhibit certain populations from accessing safe and affordable water (Miroso & Harris, 2012).

Residents in slum settlements face multiple socio-economic and environmental barriers to achieve water security (Marx et al., 2013). Slum settlements are the most deprived and excluded type of informal settlements, characterized by large agglomerations of dilapidated housing located in hazardous urban land, lacking formal supply of basic services (Habitat, 2015). As such, slums also grapple with unique contextual challenges of having settled on speculated land for generations, with limited power over its use, due to lack of land tenure security. An important pathway through which water security can be achieved for slum populations is by taking supplementary measures to improve their living conditions (Smiley & Stoler, 2020). This calls for a holistic understanding of water security and the different pathways through which it is produced.

As slum settlements are characterized by high density informal housing, residents generally lack land and housing tenure security, and public services (Golubchikov & Badyina, 2012). It is argued that slum residents' perceptions of land tenure security influence their housing investment behaviors, where only a small percentage of slum dwellers are able to invest and own houses (Gulyani et al., 2018; Nakamura, 2016; Van Gelder, 2010). Furthermore, lack of home ownership titles hinders the capacity of tenants to invest in permanent water, sanitation, and electricity connections due to fear of evictions (De Soto, 1989; Payne, 2002; Satterthwaite et al., 2005). This also excludes slum residents from municipal infrastructure coverage for water, sanitation, electricity and waste disposal (Field, 2005; Fox, 2014; Gulyani et al., 2012; Gulyani & Talukdar, 2008). Specifically, water and sanitation infrastructures demand high cost, long term investments (Bakker, 2010, 2013) posing a challenge for municipal and national governments to expand these services in tenure-lacking slum settlements (Sibanda, 2018)

To fill this gap in water service, diverse types of informal water service provision have evolved (Ahlers et al., 2013; Dardenne, 2006; Wutich et al., 2016). Informal water service providers can be defined as small scale, independent, networked private vendors or entrepreneurs,

that are not formally recognized by the government, and in many cases operate as primary water providers for low-income households and businesses in developing countries (Ahmad et al., 2003; Kariuki & Schwartz, 2005; Moran & Batley, 2004; Moretto, 2007). While the modalities of their operation vary widely, most of them supply water through tanker-trucks, kiosks, tap-points or stand posts and carrier carts (Garrick et al., 2019; Raina et al., 2019; Whittington et al., 1991). Informal water providers fill a market niche and play an important role in advancing the human right to water for slum residents (Ahlers et al., 2014; Solo, 1999; Wutich et al., 2016). However, residents that rely on informal vendors, incur high costs (Kjellén & McGranahan, 2006; Peloso & Morinville, 2014; Shah, 2007; Smiley, 2020) for water that is also considered low in quality (Bayliss & Tukai, 2011; Olajuyigbe et al., 2012; Price et al., 2021; Sarkar, 2020). It is therefore unclear whether water from informal providers mitigates water insecurity in slum settlements in terms of all key parameters - access, quantity, quality, and affordability.

Tenants in slums are especially trapped in insecurity cycles where they rely on high-priced, low-quality water, and pay high rents for living in poor housing units prone to evictions (Gulyani et al., 2014; Kim et al., 2019; Sinharoy et al., 2019; Talukdar et al., 2010). Studies based on 2004 World Bank surveys show that slums from Nairobi, Dakar and Johannesburg differ dramatically on all indicators (education, employment, household characteristics) except that slum tenants across all cities are less likely to have formal municipal water and electricity connections (Gulyani et al., 2012; Talukdar et al., 2010). Living conditions such as water and sanitation of tenants are worse than for homeowners (Gulyani et al., 2012). Specifically, Nairobi slums are characterized by high levels of tenancy, absentee ownership and deplorable basic services (Gulyani et al., 2018).

In our study, we investigate three main relationships in Nairobi slums that have not received enough attention – (1) relationship between housing tenure status (tenancy vs. ownership) and access to combinations of water service types; (2) association between access to different

water service types and water insecurity levels of households and; (3) the relationship between housing tenure status and water insecurity levels of households. To our best knowledge, there is no empirical study identifying the key link between housing tenure, access to types of water services and household water insecurity levels in slum settlements. Building on scholarship that has shown the relation between tenancy and lack of in-house water connections in slums (Gulyani et al., 2012, 2014, 2018; Gulyani & Bassett, 2007; Talukdar et al., 2010), and informal water provision in cities (Abu-Lohom et al., 2018; Cain, 2018; Garrick et al., 2019; Raina et al., 2019; Sarkar, 2020; Smiley, 2020; Wutich et al., 2016), we fill in a gap by examining the relationship between water service provision and household water insecurity in the context of insecure housing tenure (tenancy) in slum settlements in Nairobi. We do this by building on the human capabilities approach (W. Jepson et al., 2017; Sen, 1999) to understand how tenure status of households might impede the capacity of slum households to access different water services and become water secure. We measure household water insecurity, using the cross-culturally validated Household Water Insecurity Experience (HWISE) scale that accounts for various aspects of insecurity such as access, quality, quantity, safety, hygiene, psychological distress and social exclusion. In doing so, we answer the following questions:

- (1) What is the relationship between housing tenure status and household water insecurity?
- (2) What role does household tenure status play in access to different water service types among households?
- (3) How does access to different water service types, and cash and time expenditures relate to household water insecurity?

First, we begin by situating our study in three bodies of literature – (1) slum upgrading approaches and tenure security justice in slum settlements, (2) heterogeneous water service provision in cities, and (3) the linkages between tenure security and water services in slum settlements. Second, we

define water insecurity, engage with the scholarship on measures of water security, and elucidate how our conceptualization of water security draws on Amartya Sen and Martha Nussbaum's capabilities approach, also used by other water security scholars.

Next, we describe our research setting and show the relevance of asking our research questions in our study sites. In section 4, we describe how we collected, organized, and analyzed our data. We also describe how we calculated water insecurity scores and elaborate on other survey questions such as water access, housing tenure, cash expenditure and collection time on water, and household characteristics. In our results and discussion sections, we present our analysis and show the relationships between housing tenure, access to water services and household water insecurity. Even though our study focuses on Nairobi's slums, we believe that our study design could be applied to understand how housing tenure status impacts water insecurity in other similar settings. The rapid growth of the urban slum population is not a problem unique to Nairobi but a worldwide challenge, particularly in cities in Sub-Saharan Africa, Asia, and Latin America.

A.4 Housing and Water Security in Slum Settlements

We draw from three bodies of scholarship to inform our work. First, we engage with scholarship on the role of heterogeneous water service provision in cities, slum upgrading approaches and tenure security justice in slums. We also engage with scholarship on living conditions specific to Nairobi slums. Second, we define water insecurity as relevant to the study, discuss various approaches to measuring water insecurity, and the use of the capabilities approach in driving our research questions. In integrating across these bodies of scholarship, we are able to address the knowledge gap around the relationship between housing tenure status, access to water service types, and household water insecurity in slum settlements in Nairobi.

A.4.1 Tenure security and informal water services

In Africa, over half of the urban population (61.7%) lives in slum settlements (Habitat, 2016) and resort to small-scale water providers such as street vendors, water resellers, kiosks and water tankers for their water needs (Ahlers et al., 2014). Water provided by informal water providers can increase access to water in the absence of municipal services (Collignon & Vézina, 2000; Garrick et al., 2019; Solo, 1999), but this supply is often compromised in quality characterized by increased water-borne disease risk, time burden, expense, and high emotional distress among slum dwellers (Adams, 2018; Kangmennaang et al., 2020; Subbaraman et al., 2013). While informal water service providers are not officially recognized by municipal and national governments, in many cases, governments covertly encourage unofficial service provision for underserved populations (K. M. Meehan, 2014; Ranganathan, 2014; Swyngedouw, 2004). Informal vendors have become the primary source of water for many urban poor that lack formal water services (Collignon & Vézina, 2000; Kjellén & McGranahan, 2006). Informality of land, housing, water and sanitation have therefore been increasingly accepted as a mode of urbanism (Roy, 2005) in the global south and also in some parts of the global north (Deitz & Meehan, 2019; W. Jepson & Brown, 2014; K. Meehan et al., 2020).

Addressing the question of water insecurity in slums requires asking broader questions around land and housing tenure security. This is because slum residents lack legal sanctions from the government for the land that they have been living on, and as a result, the majority of slum dwellers are also tenants (Ghertner, 2008; Gulyani et al., 2014; Marx et al., 2013). Water utilities and municipal governments do not want to invest in permanent water infrastructures in slums, due to the risks of evictions, demolitions, vandalism and unpaid bills (Murthy, 2012). In fact, the push towards privatization of water provision in developing countries failed to achieve the universal piped water supply ideal in urban areas (Bakker, 2010), because it did not take into account the

land and colonial histories of slum development (Chatterjee, 2004; Gandy, 2004; Jaglin, 2002; Myers, 2011). Formal provision of numerous basic services like water remains spatially fragmented even today, especially in underserved slum settlements.

To address this challenge of urban slums, modernizing approaches gained momentum beginning in the 1950s. In sub-Saharan Africa, newly independent countries adopted policies that included both slum clearance and state led rental housing programs to support the development of rapidly urbanizing cities (Stren, 2018). Ultimately, both the strategies failed in terms of cost effectiveness and benefits to the urban poor (Huchzermeyer, 2011). By the 1980s, two approaches - slum upgrading (in-situ improvement) and sites-and-services influenced by John Turner's vision of 'minimal state', focused on granting secure tenure (formalization) and providing basic services to slum residents (Croese et al., 2016). While early implementation of these approaches achieved some noted success, they were met with criticism later, as scholars observed that it led to hybrid gentrification by middle-class households (Lemanski, 2014) and rents increased as basic services improved, making it unaffordable for the poorest urban residents (Payne, 1984; Werlin, 1999). In the coming decades, this led to international policy focusing more on institutional reform and housing finance for the urban poor. Then in the early 2000s, South American economist Hernando Desoto's compelling argument for home ownership and land titling in slums (De Soto, 2001) was received with international attention. This gave way to formalization of slums and extending land tenure through participatory slum upgrading programs (PSUP) - upgrading services in slums began to be seen as a way to legitimize the presence of slum residents, with the argument that living conditions will improve with time, as people feel a sense of permanency and invest in better infrastructure (Nakamura, 2017). However, slum upgrading has continued to meet with skepticism, as in the case of many cities, it continues to increase rent prices for tenants, with living conditions

still remaining poor in terms of water and sanitation (Gulyani & Talukdar, 2008; Johnson Jr, 1987; Sanyal, 1996; Talukdar, 2018).

A vast body of scholarship on slums in Nairobi demonstrates that slum upgrading initiatives that target land titling, benefit homeowners and middle-class rather than majority of slum residents that are tenants (Bassett, 2005; Huchzermeyer, 2008; Kim et al., 2019). Research shows that in Nairobi, Dakar and Johannesburg, slum tenants are worse off than homeowners, and that the proportion of tenants to owners in slums severely impacts living conditions. Specifically in Nairobi, tenants pay 16% higher rents than middle-class tenants even when adjusted for quality of life, and those higher rents do not lead to better living conditions. In addition, only 3% tenants have an in-house water connection, as compared to 10% owners, consequently making tenants rely heavily on informal vendors (Gulyani et al., 2012, 2014; Talukdar, 2018).

A.4.2 Water security and insecurity

Academic and policy approaches to water security have historically focused on the assessment of water scarcity. For example, Rijsberman (2006) reviews global assessments of water scarcity through the demand and supply lens in his analysis of water security. Mekonnen & Hoekstra (2016) assess global water scarcity by considering seasonal fluctuations in water availability and use. It is predicted that water scarcity might increase in the future due to climate change, which will impact water management and distribution (e.g., Cape Town). As such, research shows that contemporary shortages of clean and sufficient water among urban poor households have more to do with unequal distribution rather than scarcity of water per se (Anand, 2011; Peloso & Morinville, 2014). Therefore, water supply for many large African cities will be stressed in the future, as the increased scarcity and unequal distribution will have increased water costs passed on to households (Cameron & Katzschner, 2017; Krueger et al., 2019). Water

researchers have thus also focused on water security considering human dimensions of it, such as political, social, economic and institutional capacities at different spatial scales (Bakker, 2012; Bakker & Morinville, 2013; Gerlak et al., 2018; W. Jepson et al., 2017). Governance scholars emphasize the political and institutional dimensions that impact water security (Cook & Bakker, 2012) with better governance being associated with lower water insecurity and greater overall well-being (Miller et al., 2020). In urban contexts, water security pertains to infrastructure and capital flows (Kaika & Swyngedouw, 2000; Raina et al., 2019), as well as histories of colonialism, international development trends and modernization taking place in urban waterscapes in developing countries (Bakker, 2010, 2013; Furlong & Kooy, 2017).

Researchers from the Household Water Insecurity Experiences (HWISE) Research Coordination Network have developed a cross-culturally validated scale to measure water insecurity (Young, Collins, et al., 2019). Utilizing the scale, and drawing on a dataset from around 20 countries, studies from the network have examined the relationships between – (1) water insecurity and cash expenditures (Stoler, Pearson, et al., 2020); (2) water sharing as a widely practiced coping mechanism and a way to achieve security (Brewis, Rosinger, et al., 2019; Stoler et al., 2019; Wutich et al., 2018); (3) water insecurity as a driver of food insecurity (Brewis et al., 2020); and (4) water insecurities' impacts on mental well-being (Brewis, Choudhary, et al., 2019). With water access being the foremost requirement to prevent COVID-19 transmission, water security has become more important than ever before, as water insecurity not only affects handwashing, but also undermines many other control strategies (Staddon et al., 2020; Stoler, Jepson, et al., 2020). Researchers thus increasingly acknowledge the multifaceted nature of water insecurity in diverse contexts and at spatial scales, underscoring the importance of integrating the community context and complex water service combinations (Wutich et al., 2021). Understanding

water security in slum settlements remains particularly complex and there is little research linking water security and tenure status.

We define water insecurity as embodied in social relations and governance processes. As such, water insecurity is produced through processes of exclusion (Loftus, 2015) - slum populations' exclusion from gaining housing tenure security (homeownership) impacts their ability to access municipal water services and become water secure; in turn; this exclusion from access to municipal water services also impacts their ability to become homeowners. For instance, having access to water from municipal sources can make households' presence more legitimate, making it easier to advocate for themselves in becoming a homeowner. Given the context of slums, we conceptualize secure housing tenure (i.e., homeownership) as a capability that advances human flourishing via, among other routes, access to water services, which influences households' path to water security (Nussbaum, 1999; Sen, 1999, 2014) and broader achievement of human development and justice (Sen, 2014). As Jepson et al. (2017) describe, water security is grounded in the social relations of access to water and is crucial to a set of relations that advance human flourishing. In applying the capabilities approach in our study, we ask how secure housing tenure status as a function of social relations of access to water shapes one's access to different water services and whether this differentiated access compounds the incapability of slum households to become water secure.

A5. Research Setting

Kenya experiences a high degree of rainfall variability and is prone to water deficits and droughts (Camberlin et al., 2009; Krell et al., 2021). Domestic water availability fluctuates with rainfall patterns (Armstrong et al., 2021). In Kenya, roughly 34% of households use piped water as their source of drinking water (Kenya National Bureau of Statistics, 2019b). Per the 2019 Kenya

Population and Housing Census, only 22.7% of the population in Nairobi City received their drinking water from a piped source into the dwelling, whereas 18.9% and 15.4% receive drinking water from a public tap and/or a water vendor, respectively (Kenya National Bureau of Statistics, 2019a).

The rapidly growing city of Nairobi has a population of over 4 million with an estimated 55% of the population living in slum settlements (Mwau, Baraka et al., 2020). About 70% of housing in Nairobi is rented - where 34% of households rent a single room shack in slum settlements and 36% live in single-room informal apartment buildings (Mwau, Baraka et al., 2020). Nairobi's slum settlements pose a unique challenge of low quality but high-cost housing where poor residents pay monthly rent on average of about US\$126 (Ksh 9840) per household (Gulyani & Talukdar, 2008) for houses built on land that does not have legal title. In addition, more than 80% of households in slum settlements completely rely on private water providers (Nilsson & Nyanchaga, 2008), who price water four times higher than municipal water tariffs (Crow & Odaba, 2009). In addition to paying a high price for water, the rents and the payback period for a housing unit sold in Nairobi's slums is four times higher compared to middle-and upper income areas of Nairobi (Mwau, Baraka et al., 2020). While some scholars have suggested housing in slums eventually improves in quality and services get better (Gulyani & Bassett, 2007), these trends are not evident in the slum settlements of Nairobi, where rents and water prices are exceptionally high. Recent evidence shows that only improving land tenure might not work, and additional measures such as addressing housing tenure injustice and expanding home ownership by creating affordable options might be better for improving conditions in Nairobi slums (Gulyani et al., 2018; Kim et al., 2019).

The settlements of Mukuru Kwa Njenga, Kwa Reuben and Viwandani (hereafter referred as Mukuru settlements) compose one of Nairobi's largest slum settlements located in the industrial

zone on the southeastern periphery of the city. 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 Rueben and Viwandani are 97,890, 26,699, and 18,472 respectively (Kenya National Bureau of Statistics, 2019a). Situated primarily on privately owned lands, 94% residents in Mukuru are tenants of houses built by absentee landlords or ‘structure owners’ who do not have any legal land title (Corburn et al., 2017). ‘Structure owners’ is a locally used term for landlords in Mukuru because the structure owners do not have any ownership title of the land. This lack of land tenure is further related to infrastructure, where public services like water supply, electricity, drainage, sewerage, garbage removal are provided by private informal networks rather than municipal utility companies.

In terms of water provision, the Embakasi constituency within which Mukuru settlements are located, 94% of the households have access to a combination of formal and/or informal water sources outside of dwellings (through tanker trucks, standpipes on road transects), with only 6% populations using either a protected well or a spring as a water source (Kenya National Bureau of Statistics, 2019b). Specifically, in Mukuru settlements 97% of residents access water solely from informal water sources (Corburn et al., 2017). As such, our study respondents accessed water from two types of sources that they recognized as - informal water service providers, and formal/public water service providers.

Informal water providers are individuals who illegally tap water from government water chambers by paying bribes, store it in private tanks, and supply it to residents with a profit margin of 30-60% (Sdi.Kenya & AMT, 2017). They are locally called as “cartels”, as they charge high prices for water, and the price fluctuates between US\$0.05 - 0.1 (5-10 Ksh) or sometimes rises upto US\$ 0.5 (50 Ksh) per 20-liter barrel - this price on average being four times higher than municipal water sources such as NCWSC (Crow & Odaba, 2009; Nilsson, 2006). In terms of water

infrastructure used to supply this water - informal water providers have installed make-shift tap-points or park tanker trucks on major road transects to sell their water. In terms of physical accessibility, households walk up to the tap-points or tanker trucks, and collect water in 20-liter barrels. In some cases, informal water providers fill 20-liter barrels themselves, and deliver it to households with an extra delivery fee. However, none of our sampled households used this delivery service and walked up to the tap-points or tanker trucks to access water.

In contrast, Mukuru residents recognized formal water providers as community youth groups, non-governmental organizations (NGOs) or government boreholes that supply metered government water for free or at a constant price of US\$0.03 (3 Ksh). In terms of water infrastructure formal water providers also use tap-points (outside of their office premises) or park tanker trucks at road transects to supply water. In terms of physical accessibility to this water, households walk up to these tap-points or tanker trucks, and collect water in 20-liter barrels. Formal water providers do not have any door step service delivery facility. More generally, studies in other parts of the world (Garrick et al., 2019) describe formal water services as those operated directly by municipal governments, e.g., Nairobi City and Water Service Company (NCWSC) in the case of Nairobi. However, in our study we have characterized community youth groups and NGOs as “formal” because our study participants and other case study reports on Mukuru have identified these sources as formal water services. On probing further with our study participants on why they identified these sources as “formal”, our respondents pointed out the reason being vast price differences. Whereas informal water prices fluctuated and were expensive, community youth group or NGO water was available at a lower constant price or completely free. In Table 1, we show the differences and similarities between the formal and informal water sources as recognized by Mukuru residents.

Table A1: Nature of water provision by type of water service as recognized by the study participants

	Formal Water Service	Informal Water Service
Ownership	Community youth group, NGO, or government borehole	Private individuals
Water source	Metered government water chamber, borehole dug by government or humanitarian funding agencies	Illegal water tapping from government chambers by paying bribes
Infrastructure	Tap-points and tanker-trucks	Tap-points and tanker-trucks
Cost	US\$0.03 (3 Ksh) or free per 20-liter barrel	US\$0.05 - 0.1 (5-10 Ksh) or sometimes upto US\$ 0.5 (50 Ksh) per 20-liter barrel
Access	Households walk upto the tap-points or tanker trucks	Households walk upto the tap-points or tanker trucks. In some cases, water is delivered in 20-liter barrels with an extra delivery fee.

Urban water infrastructures, especially in slum settlements defy the clear demarcation between formal and informal. As such, many studies have challenged this dichotomy between formal and informal (Bakker, 2003, 2010), as in many cases the “informal” is facilitated by the state covertly. More generally, studies describe formal supply as the one directly from municipal or government sources. However, in our study, we use the categorizations as described in table 1 as formal and informal because our study respondents recognize them as such. We have decided to go with these categorizations in our paper to recognize the diversity of the ways in which water services are perceived as formal and informal depending on the context.

A.6 Data and Methodology

A.6.1 Data collection

Our quantitative survey design in 2020 was informed by preliminary qualitative fieldwork that was pursued for 3-months in 2019. The purpose of the qualitative fieldwork was to document the nuances and local context of different water supply services in the study sites. This mixed-methods approach provides an opportunity to test whether our qualitative observations are generalizable to our study sites (Bryman, 2006).

We conducted qualitative fieldwork activities in the three slum settlements of Mukuru Kwa Njenga, Kwa Rueben and Viwandani. Following the recommendations of Bayliss & Tukai (2011) to consult multiple sources when studying informal water provision services in slum settlements, we conducted semi-structured interviews with randomly sampled households (clients), informal water providers, and formal water providers (NGOs, community youth groups). Our team sampled 121 households and 56 water service providers by starting at 5 major road transects by skipping every four households and water service providers, and sampled the fifth available household and water service provider respectively. In collaboration with a field assistant, local to the settlements, we conducted interviews that lasted 1-2 hours with each household representative and a water service provider. Interviews with administrative officials such as neighborhood police chiefs and Nairobi City Water and Sewerage Company (NCWSC) representatives followed a purposive sampling protocol, where we interviewed five officials that specifically managed water supply issues in informal settlements. Water tap-points operated by informal water providers were also mapped with the help of community health mobilisers and Mukuru residents.

This initial fieldwork revealed a complex water story. Namely, very few residents accessed water from formal sources. For example, two semi-structured interviews with homeowners

revealed that they accessed water through community youth group tap-points, but preferred water from informal vendors because supply from formal water sources was intermittent. Majority of households (~96%) in the settlements were tenants, with very few homeowners (~4%) residing in the settlements (Corburn et al., 2017; Mwau, Baraka et al., 2020). In addition, all our sampled households lacked any in-house municipal water connection.

To understand which water sources were most accessible, reliable and affordable, and how it impacted household water security, we designed a structured household survey based upon the nuanced understanding of water access from this qualitative fieldwork. To design and administer a household survey in 2020, we randomly sampled additional households in 2019 that were different from the 121 households in the qualitative sample. Informed consent was obtained from household respondents to participate in the study and be contacted in-person or via phone. Contact information from 700 households were collected. To develop a spatial distribution of sampled households through each settlement, the data collection protocol involved skipping 10 houses and sampling the 11th house. The transect sampling loop was led by accessing 3 major road transects in two settlements - Viwandani and Kwa Njenga. In the settlement of Mukuru Kwa Reuben, sampling was conducted starting from 2 smaller transect roads through the railways tracks and the Ngong river. This systematic random sampling approach of skipping households and sampling them from each transect street, provided a representative sample of households in Mukuru settlements.

Due to COVID-19 travel restrictions, our in-person data collection was shifted to remote phone surveys. In July 2020, we contacted the 700 households sampled, of which 635 were reachable via phone, and out of these 635 households, 540 households consented to participate in the survey data collection (i.e., 85% response rate). Informed consent was obtained prior to data collection by trained enumerators. We excluded 28 observations from our analysis due to missing

values, finally having a dataset of 512 households for analysis. Data presented and analyzed in this paper comes from remote household phone call surveys.

The initial random sample ($N = 512$) included 25 respondents that were homeowners and 487 tenants. Initial descriptive statistics indicated a difference in water insecurity scores between homeowners and tenants. To increase the sample of homeowners for better understanding the role of homeownership in relation to water insecurity, we conducted a second round of data collection with households that self-identified as homeowners. We added an additional sample of 40 homeowners from a total of 44 homeowner respondents through a random sampling procedure. The additional oversampling of homeowners did not change our statistical results but provided greater confidence in representing the characteristics of homeowner households than if we were to have only relied on the initial sample of 25 owner-occupied households. We report analytical results from an aggregated dataset ($N = 556$) of the initial random sample plus the random homeowner over-sampling in the paper. For completeness we have also included results from the same statistical model run on the initial sample ($N = 512$) in our supplementary information section.

Our local research 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 group. We held online training sessions with these three enumerators in June 2020 who 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 minutes to complete. The survey was administered to one adult who self-identified as being knowledgeable about the household's water access and overall situation. Since water collection in Mukuru settlements is primarily performed by women, 65% of our survey respondents were women.

We obtained Institutional Review Board approval to conduct human subjects-based research according to data collection protocols and ethical research standards. Kenya's National Commission for Science, Technology, and Innovation (NACOSTI) granted a research permit for our study both in 2019 and 2020. Per NACOSTI, the study is affiliated with a local university, and was conducted with guidance from local research supervisors.

A.6.2 Water insecurity scores

The survey instrument administered for this study contained 12 cross-culturally validated HWISE Scale items for measuring water insecurity (Young, Boateng, et al., 2019; Young, Collins, et al., 2019). However, we excluded one item - "In the last 4 weeks, how frequently has there been no usable or drinkable water whatsoever in your household?" because it had 225 (>40%) missing values. This was because, in our study sites, the meaning of "usable or drinkable" did not yield the same meaning that the question intended, which led to our respondents to respond "I don't know" or "not applicable" to this question. We learned from our enumerators that characterizing water as usable or drinkable led to confusion among respondents, since in our study site's context water can be usable, but not drinkable. This led our respondents to respond "I don't know" or "not applicable" to that question. Since >40% respondents had missing values (i.e., I don't know/not applicable) we excluded this question from our analysis. Thus, our water insecurity score consisted of 11 items that queried the number of times in the past four weeks the household had experienced problems related to: (1) water availability [water supply been interrupted or limited, having to change plans due to unavailability of water]; (2) quantity [not enough water to wash clothes, having to change what is being cooked/eaten, no water to drink as much preferred, gone to sleep thirsty]; (3) safety [insufficient water for hand washing and bathing]; (4) psychological impacts [worrying about not having enough water, feeling angry, feeling excluded or stigmatized because of the water

situation]. Each item had likert responses scored from 0 to 3 where 0 = never (0 times in the past four weeks), 1 = rarely (1–2 times), 2 = sometimes (3–10 times), 3 = often (11–20 times) or always (>20 times). Following Young et al. 2019 and Young, Collins, et al. 2019, we generated a score for each observation (household) by summing values across the 11 items, resulting in a range of 0–33, where higher scores indicate greater household water insecurity levels. This water insecurity index variable serves as a measure to test how different households fared in terms of water insecurity experience. We chose to use the HWISE scale for the study because it was validated using cross-sectional surveys implemented in 8127 households across 28 sites in 23 low-income and middle-income countries (Young, Boateng, et al., 2019). However, it was not validated specifically in the context of Nairobi’s urban slum settlements, and this gave us an opportunity to test the scale for our specific context.

A.6.3 House tenure status, water services, expenditures, and household characteristics

Our survey instrument also included questions about the household’s tenure status, water services they primarily accessed to fulfill their water needs and household characteristics. Household tenure status was determined by asking the question, “Is the house you live in rented or owned by someone in your household?” This question was further split into asking if homeowners had any type of title or proof of ownership to gain understanding on other non-legal forms of agreements in the settlements.

Drawing from past qualitative fieldwork, we generated two measures of water access (primary source and physical water acquisition infrastructure) using two survey questions that asked, “Which type of water source does your household primarily have access to?” and “In which ways does the household primarily have access to this water?” The first question assesses whether

households access water through a formal source, namely community youth groups, government borehole or an informal source namely yard shared water connection by structure owner or private water vendor. For our analysis, we divided the responses into formal and informal water sources. The second question assesses the physical infrastructure used to access this water source namely tap-point outside the house, tap-point inside the house and water tankers outside the house. All our respondents collected water either through a tap-point or water tanker outside of the house; we therefore divided the responses into tap-point and tanker trucks.

To measure cash expenditures on water, we asked whether households paid for water on a monthly, weekly, or daily basis. Since 95% of our sample paid for water on a daily basis, we aggregated the weekly and monthly responses to reflect per day cost in local currency (Kenyan Shillings), converted to USD and reported these values in our analysis. To examine the time spent on water collection, we asked, “On a typical weekday, how much time is spent on water collection?” and recorded the time spent in minutes.

We also collected and analyzed information on household and demographic characteristics, which included the number of household members, whether the head of household was a single female, total rooms in the house, household type (apartment building vs. shack), head of household status (i.e., if the household head was a single female), and number of years lived in the house. Although we requested monthly income information from respondents, we did not include an income variable in our analysis because more than 50% of our sample declined to respond to the question. Instead, we included a household density variable (number of people per room) as a wealth and income proxy. We also expect that household type (apartment or shack) may be a proxy for wealth, since our qualitative observations suggested that households in tenements/apartments were often socio-economically better-off than those living in shacks. Table A2 and Table A3

present the descriptive statistics for the dependent variable (water insecurity score) as well as other variables included in the analysis of this paper.

Table A2. Descriptive statistics for surveyed households: Numeric data.

Variables	Mean	SD	Range	N
Water Insecurity Score	14.23	7.72	0.0 - 32.0	556
Water Collection Time (Minutes)	17.89	24.32	0.0 - 150.0	556
Daily Cash Water Expenditure (US\$)	0.36	0.26	0.0 - 3.0	555
No. Years in House (Years)	5.29	3.43	1.0 - 10.0	556
No. Regular Income Contributors	1.17	0.38	1.0 - 3.0	556
Household Density (People per Room)	2.70	1.46	0.33 - 11.0	555

Table A3. Descriptive statistics: Categorical data.

Variable	Levels	N	%
Housing Tenure Status	Tenant	491	88.3
	Owner	65	11.7
Settlement	Mukru Kwa Rueben	180	32.4
	Mukuru Kwa Njenga	149	26.8
	Mukuru Viwandani	227	40.8
Water Source - Informal Water Vendor	Yes	527	94.8
	No	29	5.2

Physical Water Infrastructure – Tap-point	Yes	446	80.2
	No	110	19.8
Single Female-Headed Household	Yes	122	21.9
	No	434	78.1
Household Type - Apartment	Yes	54	9.7
	No	502	90.3

A.7 Data Analysis

The aim of this paper is to analyze the relationships between house tenure status, access to water services, cash expenditure and collection time on water, and household water insecurity. To analyze the association between house tenure status and access to varying combinations of water services, we conducted 2x2 Pearson’s chi-squared tests. We present differences in water insecurity scores among tenants versus owners using a boxplot and use a two-sample Wilcoxon rank-sum test to test for significant differences between the two groups.

To further assess which household factors are related to household water insecurity, we performed a multiple linear regression model to understand the relationship between water insecurity and household tenure status and a suite of independent variables including infrastructure access, water cash expenditures, and water time expenditures. We hypothesized that water insecurity scores among tenants will be higher than homeowners, and informal water service providers would relate to higher water insecurity scores than formal water service providers. Our model controls for settlement with a dummy variable to account for diversity among the

geographical and socio-environmental conditions in each of the three settlements (Corburn et al., 2017). Since Gulyani et al. (2014) show that tenant occupiers in Nairobi move houses on average every three years, and that this impacts their ability to invest in formal water connections, we control for the number of years the respondents have lived in their current dwelling. We also controlled for the type of household (apartment building vs. shack), gender of household head (single female headed households vs. non single female headed households), household density (number of people per room), and number of household members who regularly contributed to income. To address multicollinearity, we removed redundancies in variable pairs for which we had theoretical reasons to expect multicollinearity (e.g., although we have data describing both “number of trips to collect water” and “time to collect water,” we included only “time to collect water” in the model). We also ran a correlation matrix with the variables in our model, and excluded variables that had coefficients ≥ 0.80 . All remaining variables in the model have correlation coefficients of less than 0.60.

$$\text{Water Insecurity Score} = \alpha + \beta_1 \text{ Tenure Status} + \beta_2 \text{ Water Source} + \beta_3 \text{ Physical Water Infrastructure} + \beta_4 \text{ Water Collection Time} + \beta_5 \text{ Daily Water Cash Expenditure} + \beta_{6-10} \text{ Controls} + \varepsilon$$

A.8. Results

A.8.1 Access to water services and household tenure status

Across the three settlements, 11.7% of sampled households were homeowners, whereas 88.3% were tenants (Table 3). Based on the difference in access to water services among both the

groups, a majority of households' access water from informal vendors regardless of their household tenure status, which includes 95.9% of tenants and 86.2% of owners (Table 4). This means that only 4.1% of tenants access water through formal vendors, as compared to 13.8% of homeowners.

Both formal and informal water providers supply water using one of two types of infrastructure: tanker-trucks or tap-points located outside households at street transects. Because these infrastructural factors (vendor type and water supply type) may be important in combination, we cross tabulate combined water infrastructure by ownership status (Table 4). Substantially more tenants than homeowners access water from informal vendors who supply water using tanker-trucks (20.6% of tenants vs. 4.6% of owners, Table 4). This difference in water infrastructure is significant according to a 2x2 Chi2 test comparing water access from informal vendors supplying water through tanker-trucks to all other forms of water access ($p=.002$). Turning next to the opposite water infrastructure scenario, substantially fewer tenants than owners receive their water from formal vendors who supply water using tap-points (2.9% vs. 13.8%, respectively); this difference is significant according to a 2x2 Chi2 test comparing water access from a formal vendor supplying water using tap-points to all other forms of water access ($p<.001$).

Table A4. Water service access by household tenure status

	Tenants	Homeowners	Total
Informal Water Service	471 (95.9%)	56 (86.2%)	527 (94.8%)
Tanker-trucks	101 (20.6%)	3 (4.6%)	104 (18.7%)

Tap points	370 (75.4%)	53 (81.5%)	423 (76.1%)
Formal Water Service	20 (4.1%)	9 (13.8%)	29 (5.2%)
Tanker-trucks	6 (1.2%)	0 (0%)	6 (1.1%)
Tap points	14 (2.9%)	9 (13.8%)	23 (4.1%)
Total	491 (100%)	65 (100%)	556 (100%)

A.8.2 Cash expenditure and collection time from formal versus informal services

To better understand the strains associated with varying forms of water access services, we examine the amount of cash and time spent on water collection. Interestingly, very few clear trends in expenditures emerge. Mean cash expenditures ranged from a low of US\$ 0.12 per day among those who rely upon formal water service providers and tanker trucks to a high of US\$ 0.37 per day among those who access water from informal water service providers and tap points. However, none of the across-group differences were significant according to a Tukey post hoc test. Mean time expenditures ranged from a low of 15 minutes per day among those who rely upon informal water service providers and tanker trucks to a high of 40 minutes per day among those who access water from formal water service providers using tanker trucks. Again, none of these differences were significant at the $p < 0.05$ level. We therefore fail to identify any significant relationships between water cash and time expenditures and water infrastructure type. Lack of significance may be driven in part by small sample sizes among those who receive their water from formal water service providers and, relatedly, large expenditure variances within the formal water service provider group.

A.8.3 Household tenure status and water insecurity

In our study sample, 11.7% of households were occupied by homeowners (Table 3). Of these homeowners, a majority of them (76.9%, N=50) did not have any certificate or title for the house. Six of the homeowners surveyed had an occupancy certificate but no title (9.2%), and one owner had the local authority's or chief's permission to build a house and reside in the location (1.5%). The remaining 12.3% of owners did not know their house tenure status.

Examining the association between house tenure status (tenancy vs. ownership) and household water insecurity, we determine that water insecurity scores tended to be higher among tenants than homeowners (Figure 1). On a scale from 0 to 33, the median water insecurity score for homeowners was 10 (Mean = 9.8; SD = 7.1), compared with 16 for tenants (Mean = 14.8; SD = 7.6). A two-sample Wilcoxon rank-sum test indicates that the median water insecurity score was significantly higher among tenants than homeowners ($Z = -4.825$, $p < .001$).

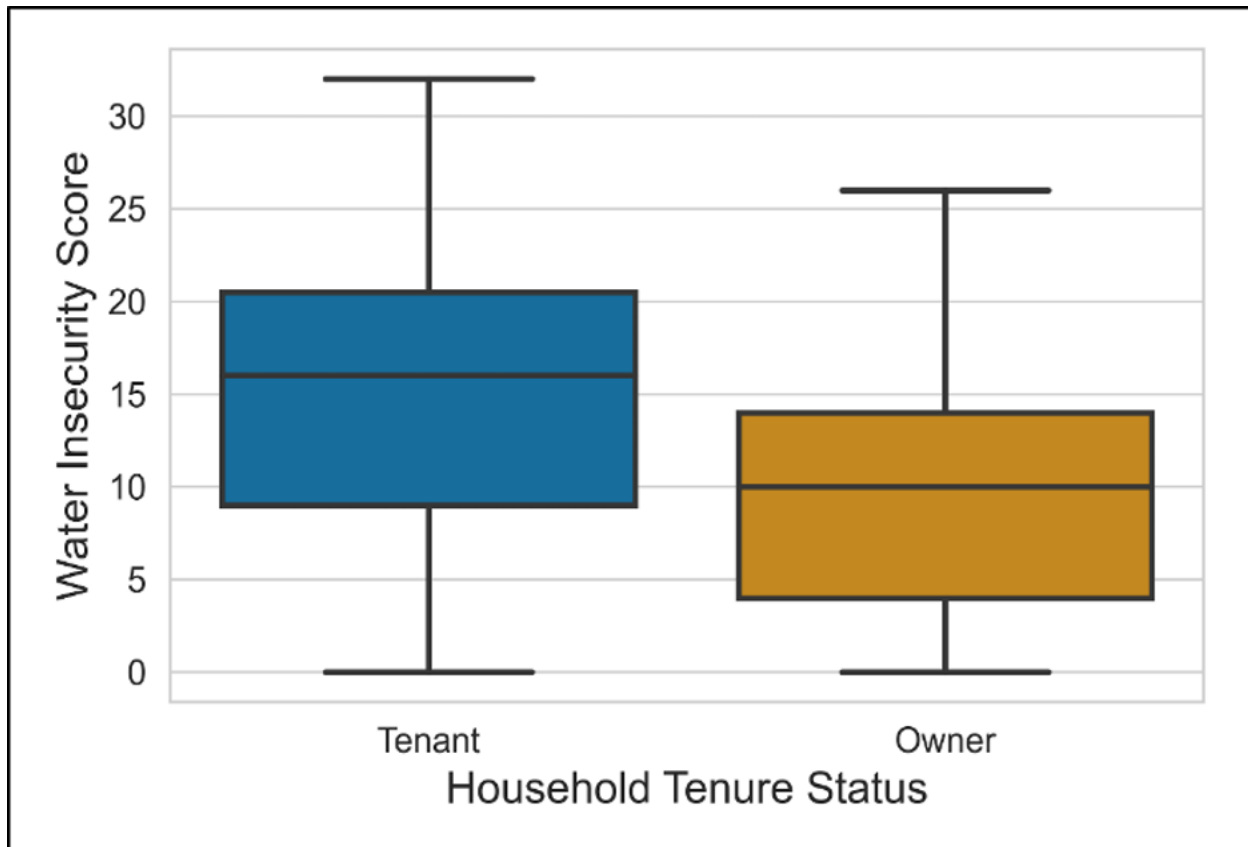


Figure A1. Boxplot showing water insecurity scores for tenants (N = 491) and owners (N = 65).

A8.4 Correlates of water insecurity in Mukuru settlements

We performed a multiple linear regression to predict water insecurity level based on household tenure status and other independent variables (Table 5 below). We identify a significant association between house tenure status and household water insecurity score, whereby tenants' water insecurity scores are 3.6 points higher than owners', all else equal ($p=.001$, $r = 3.63$). Water insecurity score was also significantly associated with water source, where households that accessed water from informal water providers had higher water insecurity than those that accessed water from formal providers ($p=.005$). Physical water infrastructures were also significantly related to water insecurity score, where households that had access to tap-points had lower levels of water insecurity than those that had access to tanker-trucks ($p<.001$). Both water collection time

and cash expenditure were significantly associated with water insecurity, where holding all other variables constant in the model, a one unit increase in collection time increased water insecurity by 1.17 points. Note that a one unit increase in collection time is not an equal interval of increased time – see Table 5 here, for how this variable was constructed. Further, one US\$ increase in cash expenditure, increased water insecurity by 2.68 points.

Table A5. Multiple linear regression with water insecurity score as the dependent variable

Water Insecurity Score	Coef.	St.Err.	t-value	p-value	[95% Conf Interval]	Sig
Tenant (ref = Owner)	3.629	1.049	3.46	.001	1.569 5.69	***
Informal Water Provider (ref = Formal Provider)	3.884	1.384	2.81	.005	1.165 6.602	***
Tap-point (ref = tanker-truck)	-3.683	.809	-4.56	.000	-5.272 -2.095	***
Water Collection Time ⁺	1.167	.311	3.75	.000	.555 1.779	***

Daily Water Expenditure (US\$)	Cash	2.683	1.181	2.27	.024	.363	5.002	**
Mukuru Rueben	Kwa	-.928	.754	-1.23	.219	-2.409	.554	
Mukuru Njenga	Kwa	1.396	.791	1.77	.078	-.157	2.95	*
No. of Years in the House (Years)		.101	.097	1.04	.297	-.089	.291	
Single female-headed household (ref = Non-single Female Headed Households)		.052	.761	0.07	.945	-1.442	1.546	
Household Type – Apartment (ref = shack)		-3.398	1.036	-3.28	.001	-5.434	-1.363	***
No. of Regular Income Contributors		-1.206	.818	-1.47	.141	-2.812	.4	

Household Density (People per Room)	.653	.217	3.00	.003	.225	1.08	***
Constant	6.356	2.281	2.79	.006	1.875	10.837	***
Mean dependent var		14.260	SD dependent var		7.719		
R-squared		0.181	Number of obs		554.000		
F-test		9.941	Prob > F		0.000		
Akaike crit. (AIC)		3751.252	Bayesian crit. (BIC)		3807.375		

*** $p < .01$, ** $p < .05$, * $p < .1$

⁺Water collection time was measured in minutes and ranked during analysis as follows – 0 minutes = 1; Upto 15mins = 2; Upto 30mins = 3; Upto 1hour = 4; Upto 2hours = 5; 2+ hours = 6

House type was significantly associated with water insecurity score, such that those who lived in apartments or tenements had significantly lower levels of water insecurity than did those who lived in shacks ($p = .001$). Household density, which also served as a proxy for income and wealth, was also significantly positively associated with water insecurity score ($p = .003$). In comparison, the type of household head (single female head or not), number of income contributors, and number of years lived in a house were not significantly associated with water insecurity scores, which further emphasizes that water security in Nairobi's slum settlements is more related to house tenure status and access to water service type than to individual household characteristics.

A.9 Housing Tenure, Water Security and Pathways Forward

Our study highlights the importance of examining housing tenure to alleviate water insecurity among slum dwellers. As such, we show how tenancy (vs. homeownership) is also related to differential access to water service types. Governments, international agencies and development banks often view housing tenure as distinct from water and sanitation infrastructure interventions (UNESCO World Water Assessment Programme, 2006). However, our findings show that water service access and insecurity are intrinsically linked with housing tenure in slum settlements. Obtaining secure housing tenure (i.e., being a homeowner) for slum households is therefore an important capability function (Sen, 1999) that could enable households to become water secure. Policy interventions will benefit from expanding home ownership among tenants, along with other approaches to increase water access such as designing regulatory frameworks that address potential negative consequences resulting from informal water vending (Raina et al., 2019). Addressing the negative consequences may entail putting a cap on water prices and subsidizing infrastructure costs for informal water providers in supplying water. In addition, contrary to recent slum upgrading initiatives that focus on land titling (Kim et al., 2019), our study shows the importance of addressing housing tenure injustices simultaneously in order to alleviate water insecurity in slums. As such, our study supports recent calls to expand home ownership and affordable housing options among tenants (Gulyani et al., 2018; Kim et al., 2019) in order to improve household water security among slum dwellers.

Our study used primary data collected from 556 households in three slum settlements in Nairobi to explore relationships between housing tenure, access to water services, cash and time expenditure on water collection, and household water insecurity score. We found a significant association between water insecurity and the tenure status of households in the study sites:

household tenants paying rent had worse water security than homeowners (a difference of 3.63 points in the water insecurity score), holding all other variables constant in the model. Since 94% of households in Mukuru settlements are tenants, the association between tenancy and water insecurity is especially notable.

In 2017, the three settlements of Mukuru were declared a Special Planning Area (SPA) by the Nairobi City County to enable participatory slum upgrading strategies there (IIED & Sdi.Kenya, 2020). Our findings emphasize that policy interventions, like the SPA, must focus on addressing housing tenure and absentee landlord issues in slum settlements rather than solely focusing on upgrading services such as water provision, sewerage, and road constructions. Furthermore, the UN Habitat guidance on adequate housing explains that legal ownership of a house in slums guarantees legal protection against forced evictions and ensures greater security for using formal water connections (UN-Habitat, 2018). Since the majority of slum dwellers across the world are tenants of house structures located on tenure-insecure land (Fox, 2014; Huchzermeyer, 2011; Marx et al., 2013; Nakamura, 2017), tackling the issue of home ownership in participatory slum upgrading programs (PSUPs) will alleviate water insecurity among many slum residents. We echo Gulyani et al. (2012) findings that increasing the proportion of homeowners in slums would be pivotal for improving living conditions for tenants and formal water access for all slum residents. Moreover, drawing from Sen's capabilities approach (1999), we argue that expanding homeownership will give increased human agency and freedom to slum dwellers, both as an end in itself, and as a means to access water and become water secure.

The association between water service access type and household water insecurity is also notable. Households who accessed water from informal water service providers had worse water security than households that primarily accessed water from formal sources such as community youth groups and government boreholes, with a difference of 3.88 points in water insecurity score.

At first, these results may seem somewhat surprising, given our qualitative field observations prior to the survey, which suggested that informal water service providers increase water access, and the wealth of previous studies indicating that informal vendors may serve to increase physical access to water in the absence of municipal water services (Garrick et al., 2019; Raina et al., 2019; Solo, 1999, 2003). However, the key distinction underlying this result is that water access and water security are not the same. Although our regression analysis did suggest that informal vendors were associated with increased physical access to water in the study sites, increased access did not translate into high levels of household water security for those who relied upon those vendors. This points to the importance of other, non-access dimensions of water security measured by the HWISE score (e.g., water availability, quantity, safety, psychological stress, and hygiene) that also shape the water insecurity experience of households. Additionally, these findings provide further evidence to complement recent studies that show how informal water markets are crucial for increasing physical access to water, but have negative consequences such as high prices, and therefore warrant policy makers' close attention and regulations (Garrick et al., 2019; Raina et al., 2019).

Consistent with our capabilities-informed framing, housing tenure was significantly associated with access to water services. In this regard, our results highlight the existence of a housing tenure and water service access nexus, through which 96% of tenants in our study sites accessed water from informal service providers, compared to only 86% of homeowners. This pattern is consistent with our expectation that tenants would be less water secure than homeowners, due in part to differences in access to water service types based on household tenure status. Being a homeowner may thus offer households an improved capacity to become water secure, as secure housing tenure is a pathway through which households access water services.

In addition to differences in water access sources, we also examined water insecurity in relation to water supply type (physical infrastructure). Our regression model showed that those who accessed water from a tap-point had better water security than those who used tanker trucks, with a difference in household water insecurity score of 3.68 points. This might be because of the narrow streets in the study sites where tanker trucks cannot reach. Members of households that accessed water primarily from tanker trucks walked longer distances when fetching water, potentially translating into their higher levels of water insecurity. Comparing water insecurity by combination of water source and infrastructure type, we found that households who relied on informal water vendors and tanker trucks had significantly worse levels of water security than all other combinations of water service types (formal and tanker trucks, formal and tap-points, and informal and tap-points). Our study therefore shows how water sources (formal vs. informal) combined with physical infrastructure type (tap-point vs. tanker trucks), and housing tenure status influence household water insecurity outcomes. These interlinkages have not been tested explicitly in prior studies, and to our best knowledge, our study is the first to test these associations in combination.

Previous research shows that there is no income threshold that allows households to earn their way out of water insecurity (Stoler, Pearson, et al., 2020), especially since slum residents access water primarily from informal vendors who sell water at highly fluctuating prices. That said, we did identify a strong association between household water insecurity and daily expenditures on water. When holding all other variables constant, a one US\$ increase in cash expenditure increased households' water insecurity by 2.68 points, and a one-unit increase in water collection time increased water insecurity by 1.16 points. Thus, households that contributed more time and money to obtaining water experienced greater water insecurity. Yet, we show that water expenditures are only a part of the burden on slum households, since our model also identified a

strong association between housing tenure and water insecurity even after controlling for financial and time costs. Reiterating our finding that housing tenure is related to water insecurity, our results therefore emphasize the wider implications at the housing tenure and water service nexus for slum populations, in which high water expenditures combined with rent payments trap tenants in insecurity cycles, and housing insecurity threatens the ability of slum dwellers to assert right to affordable water (UN-Habitat, 2018).

Although we found a positive relationship between cash expenditure, collection time and water insecurity, we found no significant evidence that increased cash expenditure and collection time were associated with the type of infrastructure access. This result might be because the combinations of informal water service types used by households in our study sites experience price fluctuations and wavering collection times, and our small sample sizes in the formal vendor group might have provided insufficient power for identifying differences. In addition, this also may be due in part to the way we identify water services as formal versus informal. Whereas formal water services are generally regarded as in-house municipal tap water services, our study participants recognized NGO and community youth group water as a formal service, so we chose to draw this same distinction. This could have influenced the lack of association with time expenditures, especially because these so-called “formal” services are not as widespread as informal water services at our study sites, which could be associated with increased travel time to access them, depending on households’ proximity. To better appreciate the full ramifications of these fluctuations, future research could compare cost and collection time for different infrastructure combinations over time, as emphasized in a recent study on water quality (H. Price et al., 2019). A comparison of expenditure data over time for differing water service types would help researchers understand the diverse realities of water access that are often masked due to a policy focus on formal piped water supply as the gold standard (Furlong & Kooy, 2017).

Some limitations about the study. Our study sites are known to struggle with water insecurity, and slum settlements in other cities might differ in context (Gulyani et al., 2014; Talukdar et al., 2010). However, this study speaks to the general issue of access to water services and varying degrees of water security, topics that are relevant across slum settlements. Previous studies suggest the potential for self-reporting respondents to under- or over-estimate water expenditures (Binet et al., 2014), but we do not expect there to be a systematic bias in under- or over-estimation by any sub-populations in our study because the expenditures reported by respondents were consistent with our qualitative observations.

Due to COVID-19 safety concerns in 2020, we collected these data remotely by conducting phone call surveys, which introduced limits on the extent to which we could ask follow-up questions and fully capture the attitudes of respondents. It was beyond the scope of our study to investigate why, for instance, more homeowners had access to formal vendors as compared to tenants, and what were the social networks at play. Future studies may benefit from taking an additional qualitative approach. Further, we were also unable to include the income variable in our analysis due to large numbers of missing values. We encourage future researchers to include wealth and/or income indexes to better understand economic differences between slum households.

Though the HWISE scale was cross-culturally validated across 23 countries and 8,127 households (Young, Boateng, et al., 2019), it was not tested in the context of slum settlements in Nairobi. One item from the scale had to be excluded from the analysis due to missing data for one of the questions that asked “In the last 4 weeks, how frequently has there been no usable or drinkable water whatsoever in your household?”. The meaning of “usable or drinkable” did not yield the same meaning that the question intended. We learned from our enumerators that characterizing water as usable or drinkable led to confusion among respondents, since in our study

site's context water can be usable, but not drinkable. By excluding the question, we adapted the scale to fit our study site's slum settlement context. In doing so, we contribute to the evolving literature on urban water security by reorienting a scale that is more appropriate to the Nairobi slum settlement context. However, excluding an item also limits our ability to compare our household water insecurity scores with other study sites that have employed the HWISE scale. Dropping a question also limited us in measuring the full range of household water insecurity experience in our study sites. Therefore, further research could explore the applications of the HWISE scale in other urban slum settlement contexts, and suggest adaptations to the scale according to the changing contexts.

Our study emphasizes the need to examine multiple aspects of water insecurity rather than reducing security to the presence or absence of formal municipal water connections. Mainstream interventions often measure security as access and quantity (supply and demand), which is important, but we emphasize the need to study the different capabilities, like housing tenure, that might also cripple a household's capacity to be water secure (Jepson et al., 2017). In doing so, we introduce the concept of a nexus between housing tenure and access to water services and its relatedness to household water insecurity. Water insecurity assessments must go beyond examining access to water, since the availability of multiple formal and informal services may increase access, but not necessarily alleviate water insecurity. Especially in the case of slum settlements, studies must consider housing tenure injustice to look further into why certain households have the capacity to be water secure while other households do not. We argue for a targeted and collaborative approach in the development community to address water security, requiring the involvement of governments, water service providers, land, and housing market players, and climate experts to ensure achievement of water security for populations of all socioeconomic backgrounds.

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

(Pre-print with Social Science and Medicine)

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B.1 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.

Keywords: COVID-19 lockdowns, employment and business disruptions, water access, hygiene, informal settlements, sub-Saharan Africa

B.2 Highlights

- Lockdown-era work disruptions added additional water access hardships.
- Daily-wage laborers were less able to afford water than small business owners.
- Reduced water access and low hygiene levels were related.
- Permanent water infrastructures and hygiene education could help reduce disease risk.

B.3 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 & Ofori-Asenso, 2020; Loftus & 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 & 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 Organization (WHO), a person needs between 50-100 liters 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 & 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 & 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 (Kangmennaang 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 & UNICEF, 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 & Ofori-Asenso, 2020; Jiwani & 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, 2020; 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, 2020). 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.

B.4 Methods

B.4.1 Research context: Kenya implemented a partial lockdown on 6 April 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, Baraka 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 & Odaba, 2009; Nilsson & 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 & Ngindu, 2007; Sobsey et al., 2003).

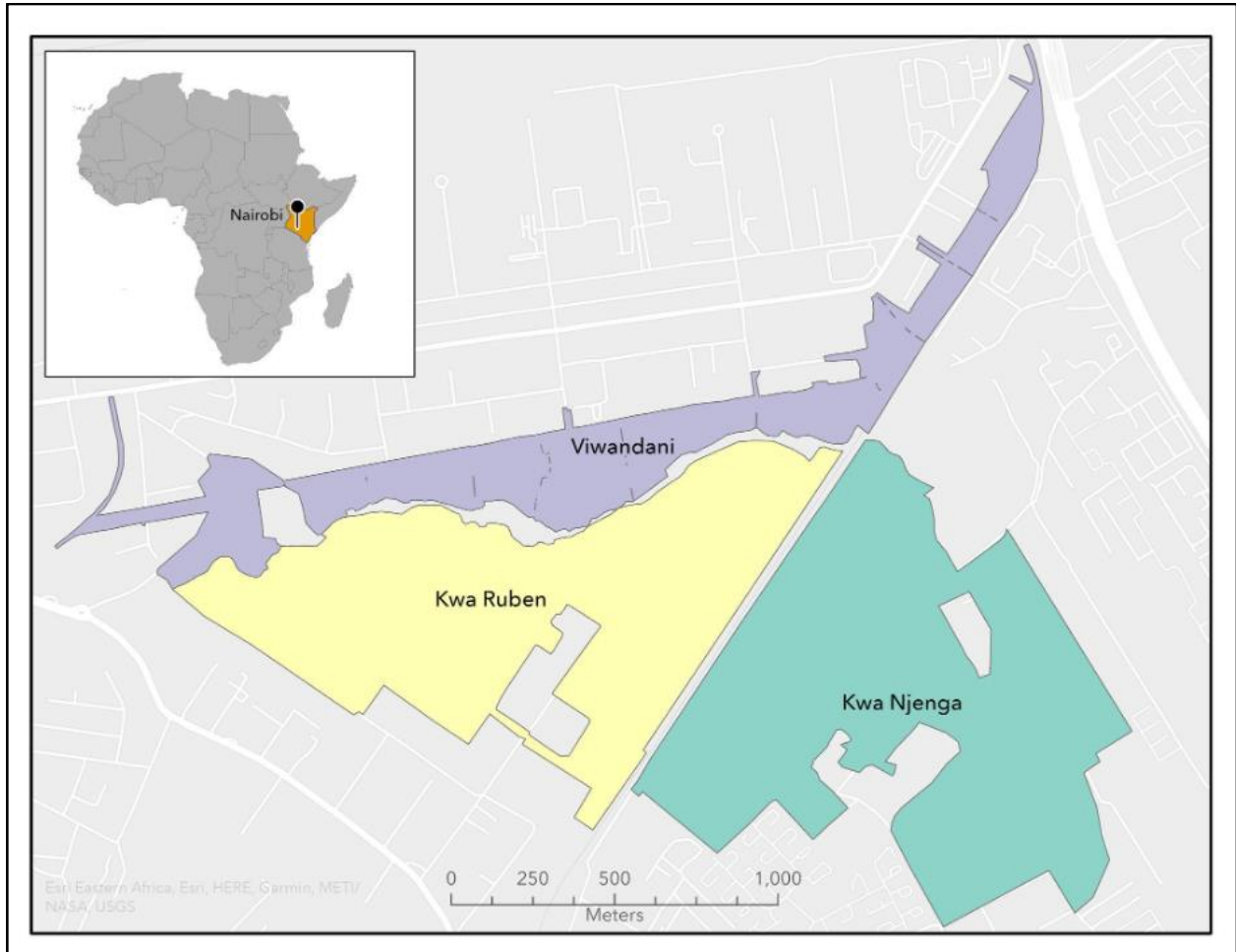


Figure B.1: Informal settlements of Mukuru Kwa Njenga, Kwa Reuben and Viwandani

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. 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 Rueben 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-liter 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-liter 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).

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

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

B.4.2 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 (>18years 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.

B.4.3 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 minutes to complete.

B.4.4 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.

B.5 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, Boateng, 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.

B.6. 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.

B.7. 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 minutes, and average daily expenditure on water collection was 0.36USD (36 Kenyan shillings) (Table 2).

Table B.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 Contributors	Income 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

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.

Table B.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

B.7.1 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 ($p=0.113$ and $p=0.746$, 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, $p=0.193$). 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 ($p=0.29$ and $p=0.77$, 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 apartment dwellers in the "business shutdown" question: business shutdowns were higher among shack residents than apartment residents (31% and 16%, respectively, $p=0.015$). 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-businesses 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.

B.7.2 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, Figure 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 affordability across these three groups was statistically significant according to a Pearson's Chi2 test ($X^2 [2, N = 532] = 20.81, p < .001$).

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 reduction in work frequently could not afford water (Table 3, Figure 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 ($X^2 [2, N = 532] = 11.18, p = .004$).

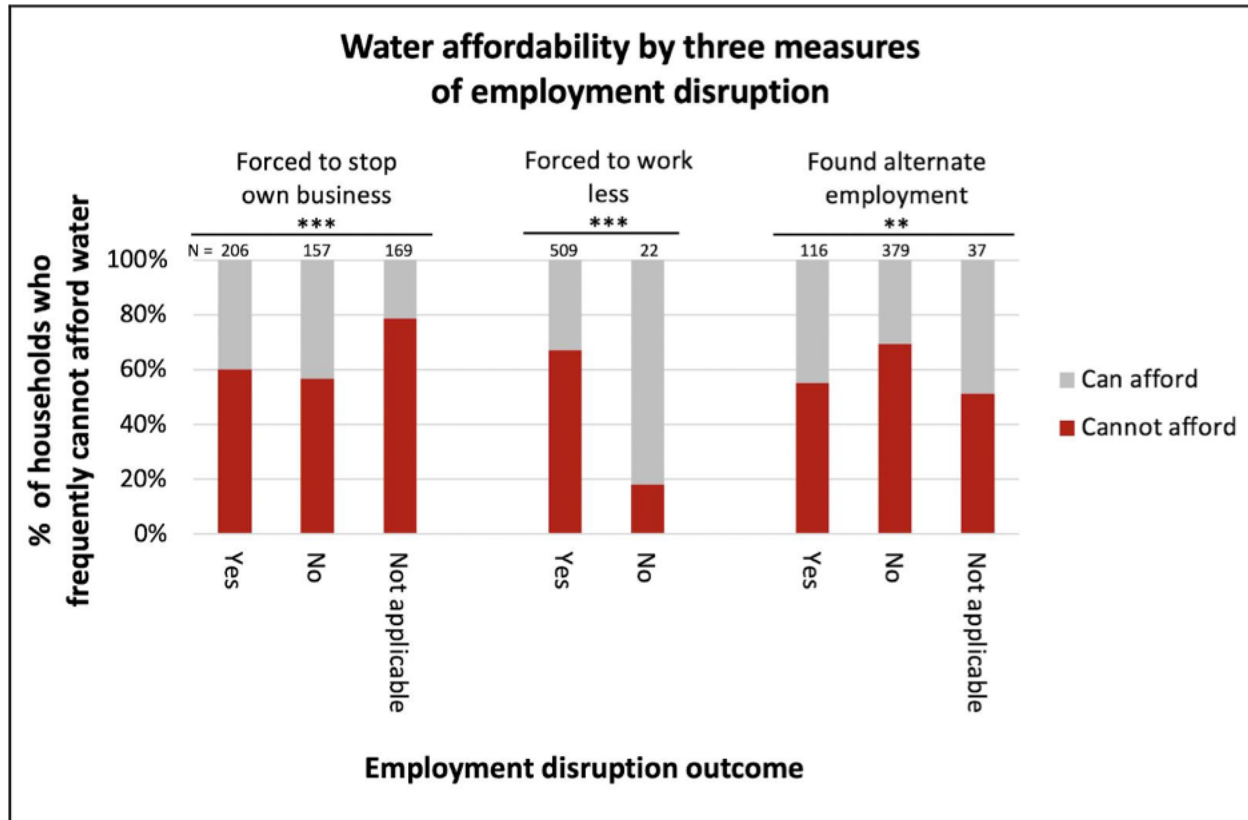


Figure B.2: Water affordability by three measures of household employment disruption during the April - June 2020 COVID lockdowns.

[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: *** $p < .001$, ** $p < .01$, * $p < .05$.

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), $1/.26 = 3.9$, $p < .001$). 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 one 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 B 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 (<i>ref = no</i>)					
Yes	.76	.19	.271	.47	1.24
Does not apply	.26***	.08	.000	.15	.46
Reduced work hours ^a (<i>ref = no</i>)	.08***	.05	.000	.02	.27
Alternate employment ^a (<i>ref = no</i>)					
Yes	1.92***	.48	.009	1.17	3.12

Does not apply	.79	.34	.586	.34	1.87
Infrastructure: Tap point (<i>ref = tanker-truck</i>)	4.26***	1.42	.000	2.22	8.20
Water Source: Informal (<i>ref = formal</i>)	.65	.33	.389	.24	1.75
Daily Water Expenditure (US\$)	1.08	.43	.84	.49	2.36
Water Collection Time ⁺	1.02	.11	.821	.83	1.26
Govt. Water Assistance	1.14	.25	.552	.74	1.75
Household Density	.82**	.07	.011	.69	.96
No. of Income Contributors	1.49	.39	.126	.89	2.49
Housing Tenure: Renter (<i>ref = homeowner</i>)	.58	.29	.272	.22	1.53
House Type: Apartment (<i>ref = shack</i>)	1.78	.59	.08	.93	3.39
Household Head: Male (<i>ref = female</i>)	.79	.19	.312	.49	1.25
Settlement (<i>ref = Mukuru Kwa Njenga</i>)	1.38	.38	.251	.79	2.37
Viwandani					
Kwa Reuben	1.58	.45	.106	.91	2.76
Constant	4.33	4.5	.158	.57	33.08

Mean dependent var	0.350	SD dependent var	0.477
Pseudo r-squared	0.156	Number of obs.	532
Chi-square	107.694	Prob > chi2	0.000
Akaike crit. (AIC)	616.941	Bayesian crit. (BIC)	693.921

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

[†]Data reflect water affordability and employment conditions since the onset of the April lockdowns.

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

B.7.3 Water affordability, availability, and hygiene practices

Next, we investigated whether household water affordability and availability during the lockdowns were related to hygiene practices. Figure 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, Figure B.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 $<.001$).

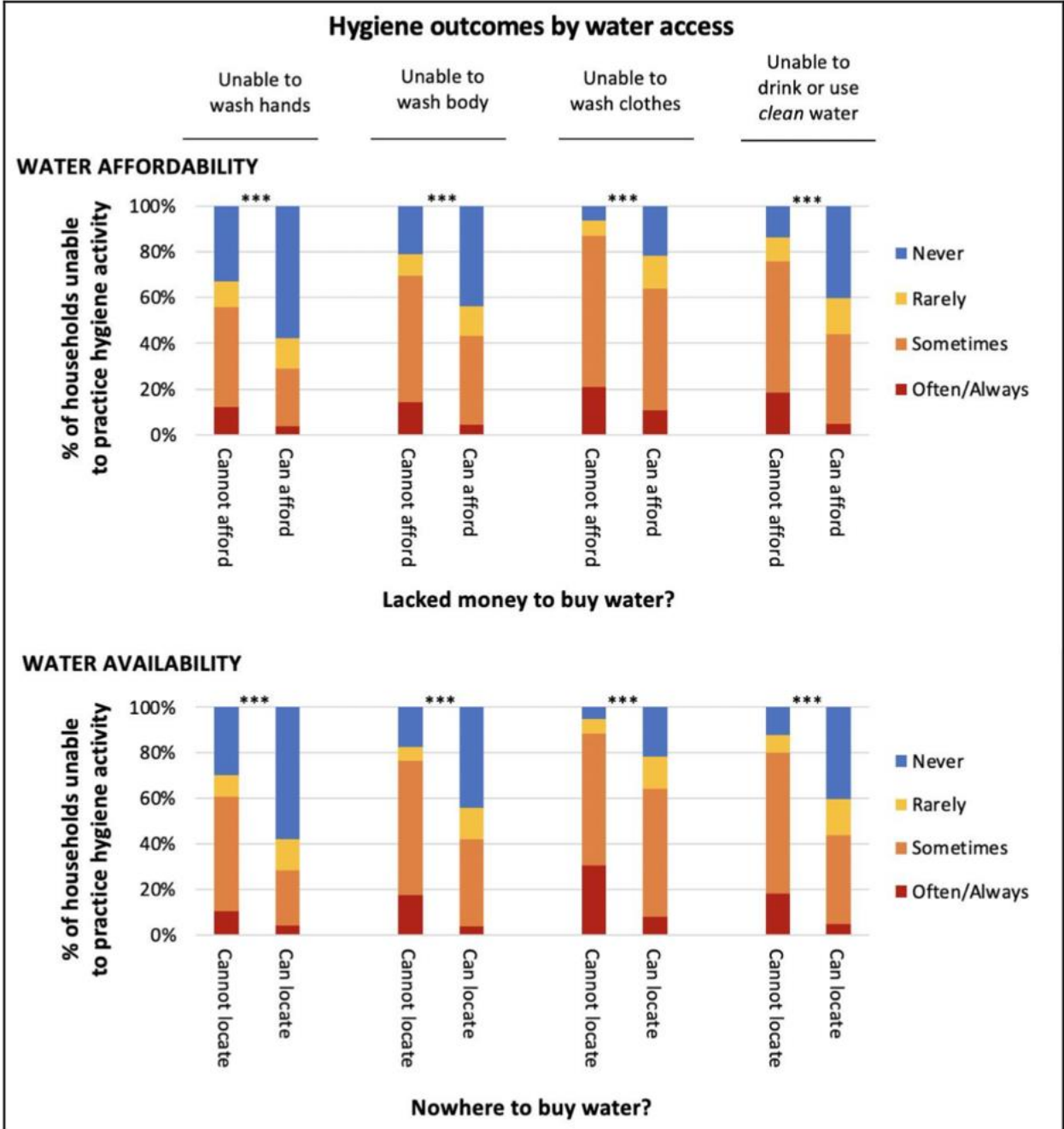


Figure B.3: Hygiene practices by households' described ability to afford and locate water in June 2020. [Never = 0 times/4weeks, Rarely =1-2 times, Sometimes =3-10 times, Often/Always = >11 times] N = 125 for “cannot afford,” 406 for “can afford,” 115 for “cannot locate,” and 416 for “can locate.” Asterisks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

Next, we combined the four hygiene practice variables into a hygiene score that ranged from 0-12, where a low score reflects a low hygiene level. Figure 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 ($M = 7.7$, $SD = 2.9$, $p < .001$).

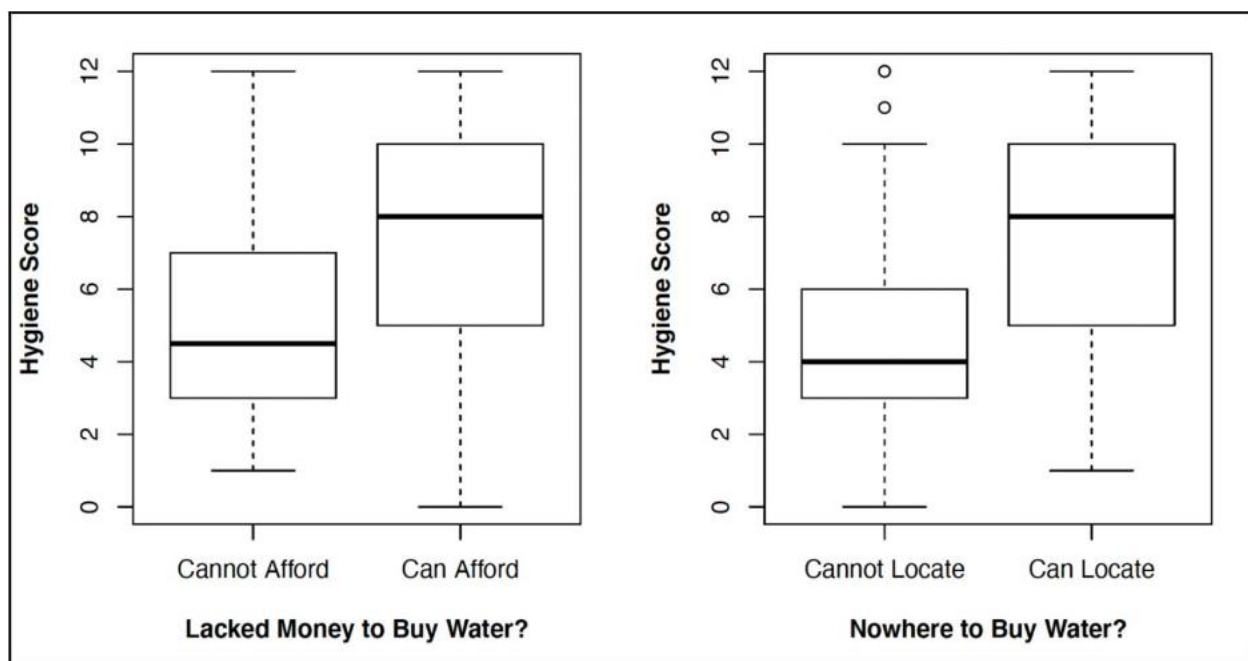


Figure B.4: Household hygiene scores (0-12) by reported affordability and availability of water in June 2020. Heavy lines represent median scores, boxes represent interquartile ranges (IQRs), and whisker lengths depict the furthest observation within 1.5 IQRs of the end of the box. $N = 125$ for “cannot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

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.

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 ($p = .001$).

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

Hygiene Score	Coef.	St.Error	p-value	[95% Conf Interval]	
Could afford water' (<i>ref = no</i>)	1.88***	.28	.000	1.34	2.42
Could locate water' (<i>ref = no</i>)	1.84***	.29	.000	1.28	2.4
Water Source: Informal (<i>ref = formal</i>)	-.53	.55	.341	-1.61	.56
Water Infrastructure: Tap point (<i>ref = tanker-truck</i>)	1.33***	.29	.000	.79	1.91
Daily Water Expenditure (US\$)	-.60	.46	.192	-1.51	.30

Water Collection Time ⁺	-.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)	.92***	.29	.002	.33	1.51
Viwandani					
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

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

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

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

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 .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 .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.

B.8 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 & Odaba, 2009; Nilsson & 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% 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 & 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 & 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 wellbeing 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 organization can best target assistance.

B.9. 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.

B.10. Acknowledgements

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B.11. References

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APPENDIX C: Where do slum households move after evictions: A study of living status of households pre- and post-evictions in Nairobi's informal settlements

(IN PREPARATION)

C.1 Abstract:

An estimated one billion people live in slums and informal settlements around the world. Growing urban populations and the proliferation of slum settlements in the cities of developing countries is an important development challenge facing urban planners and policymakers in the world today. As the global development discourse of ‘world-class cities’, and ‘cities without slums’ has become more pervasive, forced evictions have become widespread introducing severe material implications for the urban poor and their neighborhoods. As such, forced evictions of informal settlements in Kenyan cities have become widespread as the country competes to acquire global funding for foreign infrastructure investments, in turn, to make its cities desirable to foreign capital. In this paper, we present analyses of housing tenure, rent prices, and water access among 158 evicted households pre- and post-evictions in three informal settlements in Nairobi. Our results show that despite being forcefully evicted, the majority of evicted households resettled back within the three settlements and other informal areas nearby. In addition, housing tenure status among evicted households had worsened, where households were forced to live in houses shared with multiple households and in temporary tents, with rent prices increasing by 500 Ksh/month (5 USD/month) between 2020 and 2022.

Keywords: slums, informal settlements, evictions, evictions, movement, cities, Africa

C.2 Introduction

Urban populations represent over 50% of the global 7.7 billion population (UN, 2018). In many African cities, including Nairobi, the rate of urban population growth has outpaced the ability of the government to provide basic services to urban residents (Cohen, 2004; Fay & Opal, 2000). As a result, tens of millions of people across the region live in overcrowded, informal settlements with inadequate access to housing, water, electricity, and sanitation (Cohen, 2004), resulting in widespread water, food, livelihood, and housing insecurity (UN, 2018; Parnell et al., 2013). As such, the growing number of informal settlements is the result of both urbanization and population growth that are outpacing the construction of new affordable homes.

Adequate housing is a human right, and the absence of it negatively affects urban equity and inclusion, health and safety, and livelihood opportunities for urban populations (United Nations, 2018). At least 2 million people in the world are forcibly evicted every year, while millions are threatened with forced evictions often leaving them homeless, landless, and in extreme poverty and destitution (UN-Habitat, 2018). Accelerating urbanization, climate change and globalization, and financial and other global crises have also contributed to making forced evictions even more acute and complex. Forced evictions violate the right to adequate housing (Leckie, 1992). This violation of the right to adequate housing leads to spatial fragmentation and increases the risk of other human rights being compromised including loss of family ties, proximity to schools, education facilities, and working opportunities; exposure to health hazards due to inadequate living conditions, lack of access to basic services, etc. for groups who are discriminated against, marginalized and excluded (Subbaraman et al., 2014; Thiele, 2002). Furthermore, it disregards the relevance of the squatter communities and informal settlements within the urban fabric (Huchzermeyer, 2011). Evictions in informal settlements occur mainly due to two reasons.

One reason is to respond to the government's development plans for infrastructure upgrading in informal settlements under slum upgrading programs, the second is for city redevelopment projects such as road widening, construction of transport hubs, etc, that cater mainly to middle-class populations' needs, or to attract foreign (Huchzermeyer, 2008). For any purpose when evictions are forced without substitute housing or compensation, the right to adequate housing and other fundamental human rights are violated (Otiso, 2002).

The last five decades have seen increasing global attention on the need to tackle the emergence and growth of slums or informal settlements across the world's cities. The second United Nations (UN) Conference in Istanbul, in June 1996 (Habitat II), which gave birth to the Istanbul Declaration on Human Settlements, marked a significant turning point in the global policy discourse on the need to ensure "adequate shelter for all" (UN-Habitat, 2007). This policy agenda was later given fresh impetus within the framework of the UN Millennium Development Goals (MDGs), and later the Sustainable Development Goals (SDGs), to significantly improve the lives of over one billion slum dwellers by the year 2030 (UN-Habitat, 2010). In order to localize this global agenda, several countries across the developing world (for example Kenya, India, Brazil, Mexico, etc.), have initiated national programs on the upgrading of slums (Majale, 2008; Otiso, 2003; Rigon, 2014).

Beginning in the 1950s, in sub-Saharan Africa, newly independent countries adopted policies that included both slum clearance and state-led rental housing programs to support the development of rapidly urbanizing cities (Stren, 2018). Ultimately, both the strategies didn't work in terms of cost-effectiveness and benefits to the urban poor (Huchzermeyer, 2011).

By the 1980s, two approaches - slum upgrading (in-situ improvement) and sites-and-services gained momentum. This approach was focused on granting formalization to informal

settlements and providing basic services (Croese et al., 2016). Through formalization, the government legally recognized informal settlements and made investments in improving basic services there (Cronin & Guthrie, 2011). While early implementation of these approaches achieved some noted success, they were met with criticism later, as scholars observed that it led to hybrid gentrification by middle-class households (Lemanski, 2014). Improvement in basic services led to increasing in rent prices making it unaffordable for the poorest of the households in the informal settlements (Payne, 1984; Werlin, 1999). This again drove away poor households out of the upgraded area to form new informal settlements where living was affordable. In the following decades, this led to international policy focusing more on institutional reform and housing finance for the urban poor. For instance, the UN-Habitat encouraged the formation of private companies to give affordable loans to urban poor populations to buy houses or improve basic services in the areas (Jones, 2012). Then in the early 2000s, South American economist, Hernando Desoto's compelling argument for home ownership and land titling in informal settlements (De Soto, 2001) received international attention. This gave way to formal recognition of land injustices. There was a strong push for extending land tenure to households through participatory slum upgrading programs (PSUP) (Croese et al., 2016). Upgrading services began to be seen as a way to legitimize the presence of informal settlements, with the argument that living conditions will improve with time, as people feel a sense of permanency and invest in better infrastructures (Croese et al., 2016; Nakamura, 2017). However, informal settlement upgrading has continued to meet with skepticism, as in the case of many cities, it continues to evict and displace people, with living conditions still remaining poor in terms of water and sanitation services (Gulyani & Talukdar, 2008; Johnson Jr, 1987; Sanyal, 1996; Talukdar, 2018).

On October 8th, 2021, more than 75,000 residents of informal settlements of Mukuru Kwa Njenga, Kwa Reuben, and Viwandani in Nairobi faced government bulldozers that suddenly demolished their houses and businesses (Owade & Wairimu, 2022). More than 90% of this sprawling area, specifically Mukuru Kwa Njenga has disputed ownership status, and was demolished for clearing the path for road expansion - the new road called the 'road for the rich' (Ram, 2021). Many households became homeless overnight, some fled to live with friends and relatives in other informal settlements nearby, and some moved to other towns in Kenya. One of our respondents expressed, "My house and business premises were demolished suddenly without any notice and now I live in a tent and work in a factory nearby that pays too low to meet my daily needs and rebound back from this devastation." However, evictions aren't a new phenomenon for Mukuru residents. Since early 2020, there had been several gradual evictions in the settlements for upgrading basic services under the Special Planning Area (SPA) declaration. What was different about the evictions and evictions that occurred in October 2021 was that they happened suddenly, and incurred severe losses for the residents for the purposes of building a road that was not meant to serve the informal settlement populations (Ram, 2021).

In this paper, we present results from the analyses of 158 households in the settlements of Mukuru Kwa Njenga, Kwa Rueben, and Viwandani that were evicted during the year 2021 and in early 2022. In doing so, we compare household level indicators of the same 158 households for the year 2020 and in 2022 after the households were evicted. The initial data collection (2020) was not conducted with the knowledge that evictions were imminent -- the pre-survey was intentionally designed as a representative sample of the pre-eviction population. Necessarily only a subset of households in the initial survey was evicted in 2021 and in early 2022. The combined pre-post data provide a unique opportunity to investigate whether specific characteristics (both households and

settlements) were disproportionately affected by the eviction. It also provides a unique opportunity to investigate living situations pre-post with the possibility of tracking households in successive waves to evaluate the time to recovery whereby a household returns to the same living condition status as pre-eviction. Thus the sample of 158 households.

First, we start by describing the community-level characteristics of the settlements, followed by presenting household-level characteristics of the 158 households from our 2020 dataset. We then compare changes in selected household characteristics such as housing tenure, rent prices, and water access and security experience before and after the evictions. In doing so, we ask the question -

(1) What were the changes in living conditions among the evicted households?

In analyzing the before-after living conditions, we particularly compare housing tenure, rent prices, and water access and security for the 158 households. Next, we report on the household's self-reported reasons for their eviction, whether they were informed by anyone, and if yes, by whom? We discuss the losses described by households and the limited aid they were provided by civil society and their community after the evictions. Following this, we track the movement of the 158 households by asking -

(2) After the evictions, where did the households move and why?

We investigate this question because it is argued that when evictions occur, slum households either move back to the same settlements from where they were evicted or settle into other informal areas forming new slums or increasing the population density of the existing ones. To our best knowledge, there has not been any study spatially showing the movement patterns of evicted households and the reasons behind these movements.

Following this, we discuss the barriers to measuring household level post-eviction status in informal and slum settlements. We discuss the challenges in collecting information on household level income, and wealth indices as a result of households splitting and dispersing because of evictions. In addition, we acknowledge the underrepresentation of evicted households as we may have lost households who had more severe impacts making it impossible for us to reach these households. Through this analysis, we argue that without tackling the underlying causes for informal settlement formations and providing suitable rehabilitation to the evicted households, the evicted community often returns to the same informal settlements or somewhere nearby eventually forming new slums or increasing the population density of the existing slums. These issues will continue to persist despite the fact that the right to adequate housing is guaranteed to all and a prerequisite to inclusive and sustainable urban centers. Rapid urbanization in low- and middle-income countries has been accompanied by the rapid growth of highly vulnerable urban communities living in informal settlements, which are at high risk of getting evicted as they are built outside formal laws and regulations (Zazyki et al., 2022). Informal settlements also lack piped water or adequate provision for sanitation, drainage, and public services, and many are located on land at a high risk of climate change effects (Satterthwaite et al., 2020). In addition, since early 2020, the COVID-19 pandemic has exacerbated all these already existing risks and introduced new shocks in the already stressed informal settlement households (Joshi et al., 2022).

C. 3 Data Collection

The data used in this paper was collected in two phases using household surveys administered in July 2020 and April 2022.

Phase 1 (July 2020): Our quantitative survey in 2020 was informed by preliminary qualitative fieldwork that was pursued for 3-months in 2018 as well as 2019. The 2020 survey was administered mainly to understand water, food, employment security, and COVID-19 related hardships in the three settlements during the pandemic. Due to COVID-19 travel restrictions, we administered the surveys over the phone. However, the sampling of households was conducted in the summer of 2019 in-person. In 2019, we developed a spatial distribution of sampled households through each settlement, where we skipped 10 houses and sampled the 11th house. This systematic sampling approach of skipping households and sampling them from each transect street, provided a representative sample of households in the three study sites. We obtained informed consent from household respondents to participate in the study and be contacted in-person or via phone. In 2020, we contacted the 700 households sampled, of which 635 were reachable via phone, and out of these 635 households, 540 households consented to participate in the survey data collection (i.e., 85% response rate). Informed consent was obtained prior to data collection by trained enumerators. The 2020 data presented in this paper for 158 households comes from this bigger set of 540 households.

Phase 2 (April 2022): In April 2022, we contacted 532 households via phone out of the 540 households from the July 2020 dataset that consented to be contacted for another round of surveys. Out of the 532 households contacted, only 351 household contact numbers were reachable in April 2022. Out of these 351 households, 11 households denied participation. Finally, we obtained informed consent from 340 households to conduct surveys with them. The purpose of this survey was to track water, food, employment security, and COVID-19 related hardships in the three settlements, but also understand the number of households evicted, reasons for the evictions, and

the movement of households if they were evicted. For the purpose of this paper, we present analyses of 158 evicted households from the dataset of 340 households for whom we have complete data for the years 2020 and 2022.

In both the phases, our local research team consisted of three enumerators fluent in Kiswahili and Kikuyu conducted the household phone surveys. These enumerators had previous in-person data collection experience over several field campaigns with our research group. We held online training sessions with these three enumerators in June 2020 (Phase 1) and March 2022 (Phase 2022) who 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 minutes to complete. We obtained Institutional Review Board approval to conduct human subjects-based research according to data collection protocols and ethical research standards. Kenya's National Commission for Science, Technology, and Innovation (NACOSTI) granted a research permit for our study both in 2020 and 2022. Per NACOSTI, the study is affiliated with a local university, and was conducted with guidance from local research supervisors.

Finally, this paper includes analyses of data from 158 households in 2020 and 2022, that were evicted during 2021 and in early 2022.

C.4 Research Setting

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, the three settlements are home to 351,702 residents and 143,061 households (Kenya National Bureau of Statistics, 2019a). 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, 2019b). The settlements for the most part are situated on private lands and part public lands set aside for other public uses such as utility, riparian, road, and railway reserves (Corburn et al., 2017). The private registered owners of these lands are beneficiaries of conditional grants made to them by the state for the development of light industries (Sdi.Kenya & AMT, 2017). Despite the special conditions that required the land owners to develop their lands within a period of two years, these grantees left their lands idle for more than 30 years and the lands were in time occupied by slum dwellers. Currently, the titles of these lands on which the settlements are located is disputed (IIED & Sdi.Kenya, 2020).

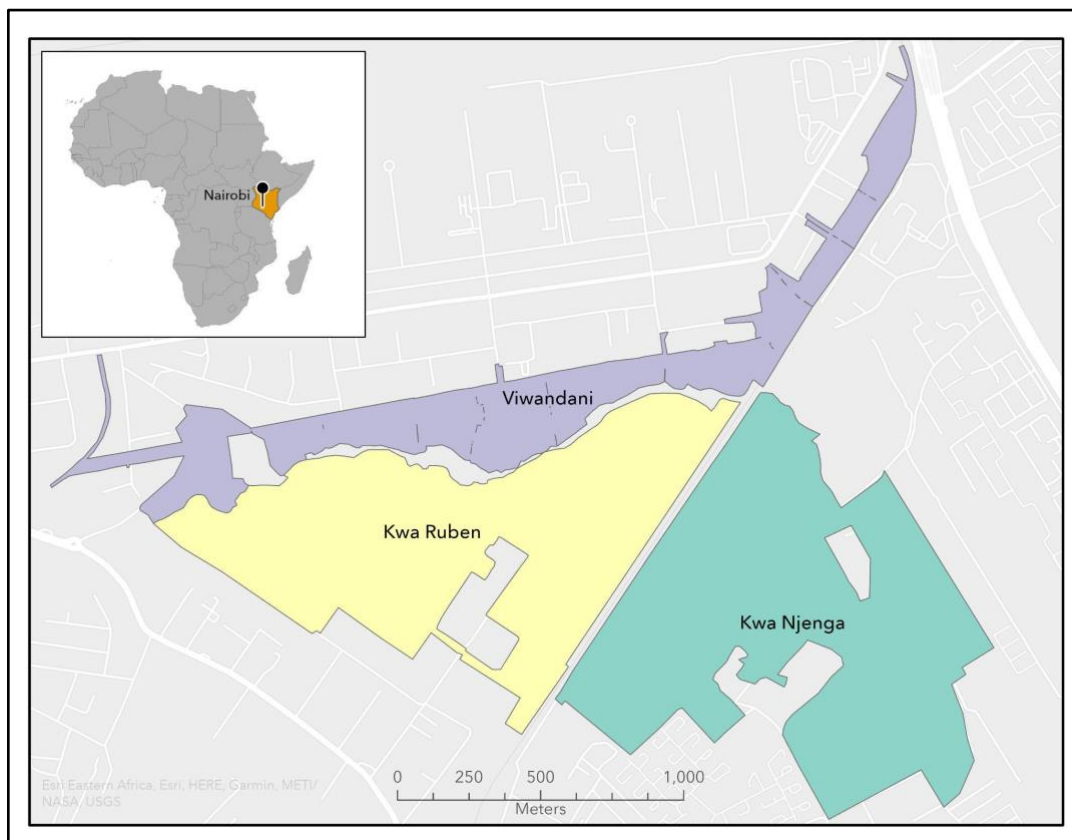


Figure C.1: Three settlements of Mukuru Kwa Njenga, Kwa Reuben, and Viwandani

Given these challenges, in August 2017, Mukuru Kwa Njenga, Mukuru Kwa Reuben, and Viwandani settlements were declared as Special Planning Area (SPA) by the Nairobi City County (Sdi.Kenya & AMT, 2017). This declaration was made due to the various development challenges

and opportunities faced by the residents in the settlements. The main objective of the Mukuru SPA is to create an integrated development plan that addresses the structural and complex problems experienced by the residents (Corburn et al., 2017).

C.5 Nature of Ongoing Evictions and Household Living Conditions

In the last 2 years (2020-2022) the three settlements have seen 2 main types of evictions.

1) Gradual evictions to redevelop the settlements as part of the SPA. Thousands of residents have been displaced within Mukuru SPA area as a result of ongoing developments. In Mukuru Kwa Reuben, SPA works involved construction of roads, condominium sewerage and water connection according to plans developed by the community.

2) Sudden evictions due to Nairobi city redevelopment plans in Mukuru Kwa Njenga residents are affected by two major developments taking place there: One is about Orbit Chemical and expansion of road infrastructure by Kenya National Highways Authority (KENHA) and Kenya Urban Roads Authority (KURA).

We now present household and demographic characteristics of households from 2020, before the evictions occurred. In 2020, when we conducted our survey with the households for the first time, we interviewed an adult in the house who claimed to be knowledgeable about their water situation. Since water collection is done by women in our study sites (Corburn et al., 2017), our respondents happened to be mostly women (69%). The age of the survey respondents ranged between 20 - 68 years, and the mean age of the respondents was 34 years (median = 32 years, sd = 10). The education level of our respondents ranged from not being formally educated to having bachelors degrees, diplomas, and vocational training. A majority of respondents had completed secondary school (36%), and only 4% had continued on to pursue a bachelor's degree or a diploma at the College level. Only 4% had pursued vocational training in plumbing, electrical, or vehicle

mechanics. The remaining 29% of the respondents had completed at least primary school, whereas 13% respondents hadn't completed primary education or had no exposure to any formal education.

In our sample, only 30% of the households were female headed households, whereas 70% were male headed. The majority of household heads (77%) worked as daily wage laborers in factories nearby, or as uber or boda-boda (local motorcycle transport) drivers, whereas 23% of household heads had their own small businesses such as food carts, beauty salons, and retail shops. During the lockdowns between April and June 2020, 95% of the 158 evicted households whose heads worked as daily wage laborers, reported having to reduce work hours, and 37% of business owning households reported having to shut down their business due to the lockdowns. Majority of the sampled households lived either in shacks that shared a wall with other shacks or shacks that did not share a wall, and in storey buildings. We therefore combined the “shared wall and without shared wall” categories into one category called shacks, and kept the storey building/ apartments category as is. Out of the 158 households, 91% lived in shacks (143 HHs) as compared to 9% in story buildings. A majority of these houses (91%), were single-room houses with an average family size of 4 members living in them.

The most prominent languages spoken among the households were Kamba (25%), Kikuyu (19%), Kisii (16%), Luhya (14%), and Luo (9%). Around 21 households (13%) responded that they only spoke Kiswahili and no other languages. Only a small number of households spoke other languages such as Kuria (3 HHs), Embu (1 HH), and Somali (1 HH).

C.6 Change in Household Characteristics: Pre and Post Evictions

Before the evictions occurred, households had lived in the three settlements for long periods of time. As of 2020, out of 158 households, 60% of the households had lived in the three settlements for more than 10 years, 38% of the households had lived in the settlements between 2-

9 years, and only 2% households were recent migrants who lived in the settlements for a year or less.

C.6.1 Changes in housing tenure and rent prices through 2020-2022

In 2020, out of the 158 households, 98% were tenants of the houses they were residing in, and the remaining 2% households (3 HHs) had no legal title for the houses they owned. Whereas before the evictions occurred, there was improvement in housing tenure status, where more households had become homeowners - 12% of the households (19 HHs) reported being homeowners. Out of these 19 households, 15 households (79%) had no legal title of ownership, whereas four households reported having a written agreement with the seller. The remaining 137 households (88%) remained tenants of the houses they lived in.

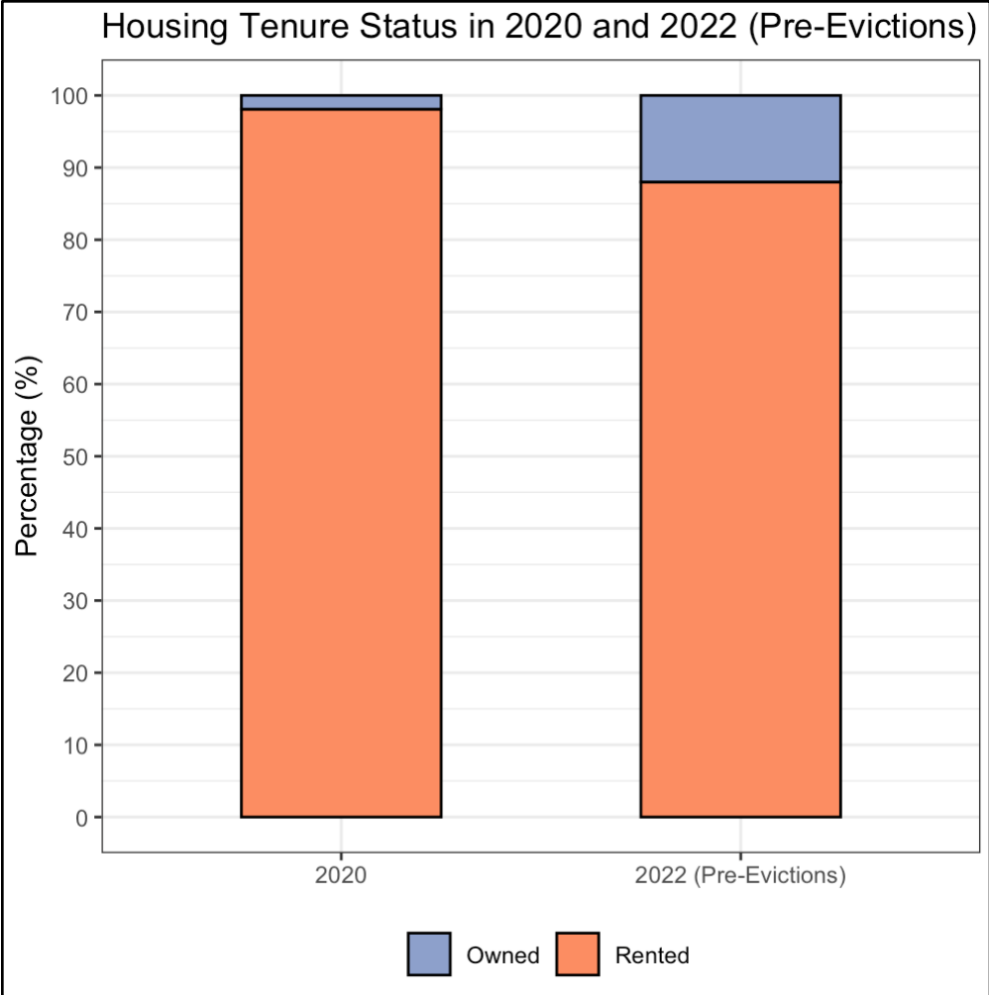


Figure C.2: Housing tenure status pre-and post-evictions

Out of the 158 evicted households, 48 households (30%) were evicted between January to September 2021, and 110 (70%) were evicted between October 2021 to March 2022. Overall, out of the 158 evicted households 47% (74 HHs) moved to houses that were permanent structures shared among multiple households, whereas 48% (76 HHs) moved to houses that were permanent structures but not shared among multiple households. Five percent of the evicted households were living in temporary structures such as cloth tents. In Table 1 we show the change in living status of the evicted households by the two time periods. We have divided these evictions into these two time frames because, during the first period households were evicted gradually for upgrading

services within the slums, whereas in the second period, houses were suddenly demolished using violent methods such as government bulldozers.

Table C.1: Change in house types after evictions

Living Conditions	After Evictions
Permanent structure - shared between households	74 (47%)
Permanent structure - not shared between households	76 (48%)
Temporary structure - Tent	8 (5%)
Total	158 (100%)

On investigating the tenure status of these housing conditions after the evictions, only 3 out of the 12 homeowner households were able to move and live in houses owned by them after the evictions. All other households, either lived in houses that were rented by them, or houses that were rented or owned by their friends or relatives, or were living in temporary tents. Table 2 shows the distribution of tenure status by households' current living status.

Table C.2: Distribution of tenure status after evictions by households' current living status.

Living Conditions After Evictions	Tenure Status After Evictions				Total
	Owned by respondent	Rented by respondent	Rented by friend or relative	No ownership or rent	
Permanent structure - shared between households	1 (1%)	66 (42%)	7 (4%)	0 (0%)	74 (47%)
Permanent structure - not shared between households	2 (1%)	70 (44%)	3 (2%)	0 (0%)	75 (48%)
Temporary structure - Tent	0 (0%)	3 (2%)	0 (0%)	6 (4%)	9 (5%)
Total	3 (2%)	136 (88%)	10 (6%)	6 (4%)	158 (100%)

Overall, tenure status among the evicted households went through some massive changes. In 2020, only 2% of the sampled households were homeowners whereas, after a year 12% of the 158 households had become homeowners. However, after the households were evicted, only 2% of these households were able to live in houses they owned whereas 98% of the households again lived in rented houses - rented either by themselves or rented by a friend/relative, or in temporary tents.

In 2020, the 155 tenant households paid a rent that ranged between 1000-7000 Kenyan Shillings (Ksh), with the mean rent being 2,475 Ksh, median rent being 2000 Ksh (sd = 945 Ksh). In 2021 and 2022, before the evictions, the 139 tenant households paid higher rents ranging between 1500-7000 Ksh, with mean rent increasing to 2,633 Ksh, and median rent going up to 2300 Ksh (sd = 1034 Ksh). After the evictions, the 139 households that paid rent for the houses they were living in, paid rents that ranged between 1500-7000 Ksh, with the mean rent remaining the almost same - 2,639, with median rent increasing to 2500 Ksh (sd = 1026 Ksh). Figure 3 shows the median rents for 2020 and 2022 before the evictions and after the evictions.

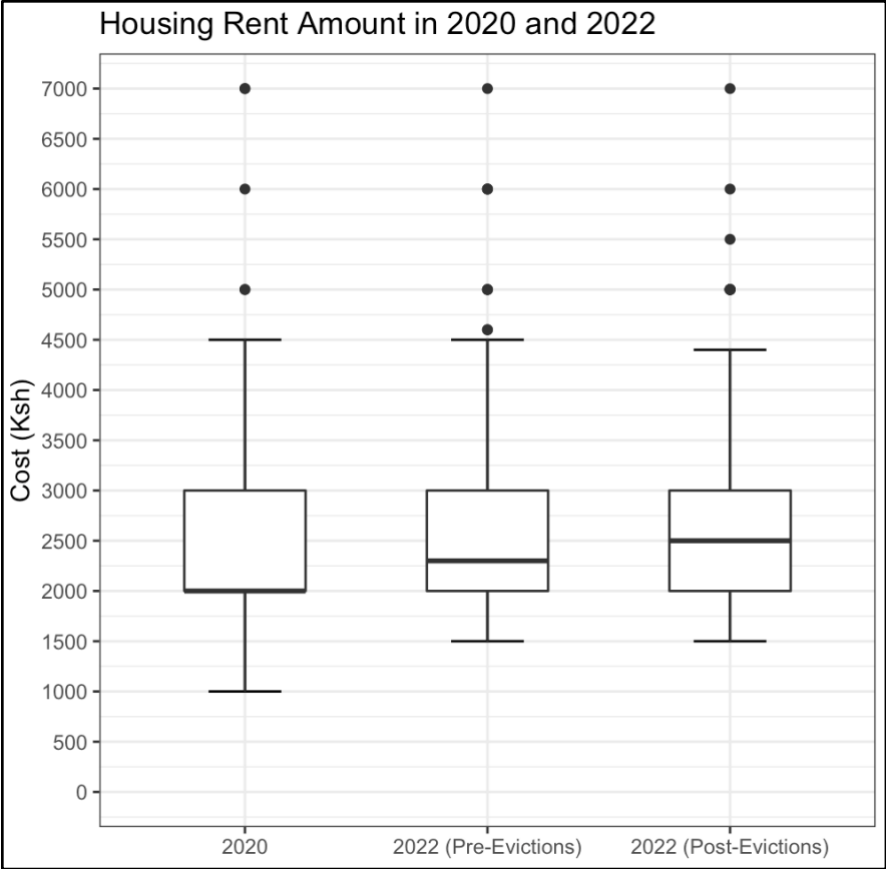


Figure C.3: Housing rent from 2020 to 2022 (pre-and post-evictions)

C.7 Change in Water Access: Pre and Post Evictions

We present analysis of change in water sources (formal vs. informal), water infrastructure types, daily cash expenditures, time spent on collecting water, and the water insecurity index. We present the post-eviction data for water insecurity scores by eviction period because since water situation is fluctuating in the settlements, and our questions have a 4 weeks recall, so we anticipate that January - September 2021 evicted households would fare differently on these indicators than households that were recently evicted between October 2021 - March 2022.

C.7.1 Water services

We categorized water sources in the study sites into formal water sources and informal water sources. Formal water sources include government borehole, community youth groups, and

services by Nairobi Metropolitan Services (NMS). Informal water sources include informal water providers that are individuals locally called as ‘cartels’. Only 3 households in 2022 after evictions reported accessing water from the Ngong river using 20-liter barrels. In combination with these sources, formal and informal service providers use two types of infrastructures to supply water - stand-pipes/tap points on road transects and tanker trucks parked at larger road transects. Table 3 shows the change in distribution of these combinations pre and post evictions. None of the households in our study sample had piped water inside their house.

Table C.3: Water Service Types pre- and post- evictions

	Formal Water Sources		Informal Water Sources		Total
	Standpipes/Tap-points	Tanker trucks	Standpipes/Tap-points	Tanker trucks	
2020	3 (2%)	2 (1%)	115 (73%)	38 (24%)	158
2022 (after evictions)	39 (25%)	6 (4%)	96 (62%)	14 (9%)	155

*3 households reported using water directly from a river or a spring in 2022 after the evictions

Overall the percentage of households accessing water from formal sources increased by 26%, that is in 2020 only 3% of the households accessed formal water sources, whereas by 2022, despite the evictions, 29% of the households used formal water sources. This shows that despite the evictions and the ongoing pandemic, water services in the settlements improved.

C.7.2 Water cash and time expenditures

More than 75% of our households paid for water on a daily basis, therefore we present daily cash expenditure on water for all households. In 2020, 158 households in our study sample, spent Ksh 0-171 to buy water on a daily basis, with the mean expenditure being 37 Ksh/day, and median cost of water being 30 Ksh (sd = 24 Ksh). In 2021 and 2022, after the evictions, the 158

households spent Ksh 0-300 to buy water on a daily basis, with the mean cost slightly reducing to 35 Ksh/day, and the median expenditure being the same - 30 Ksh (sd = 37 Ksh). Figure 4 shows box and whiskers plots of the median cash water expenditure for 2020 and 2022 after the evictions. While we didn't find any striking differences between the mean water expenditures pre and post evictions despite more households accessing formal water sources, the range in which households paid increased by ~130 Ksh after the evictions. This is surprising given that more households were using formal sources.

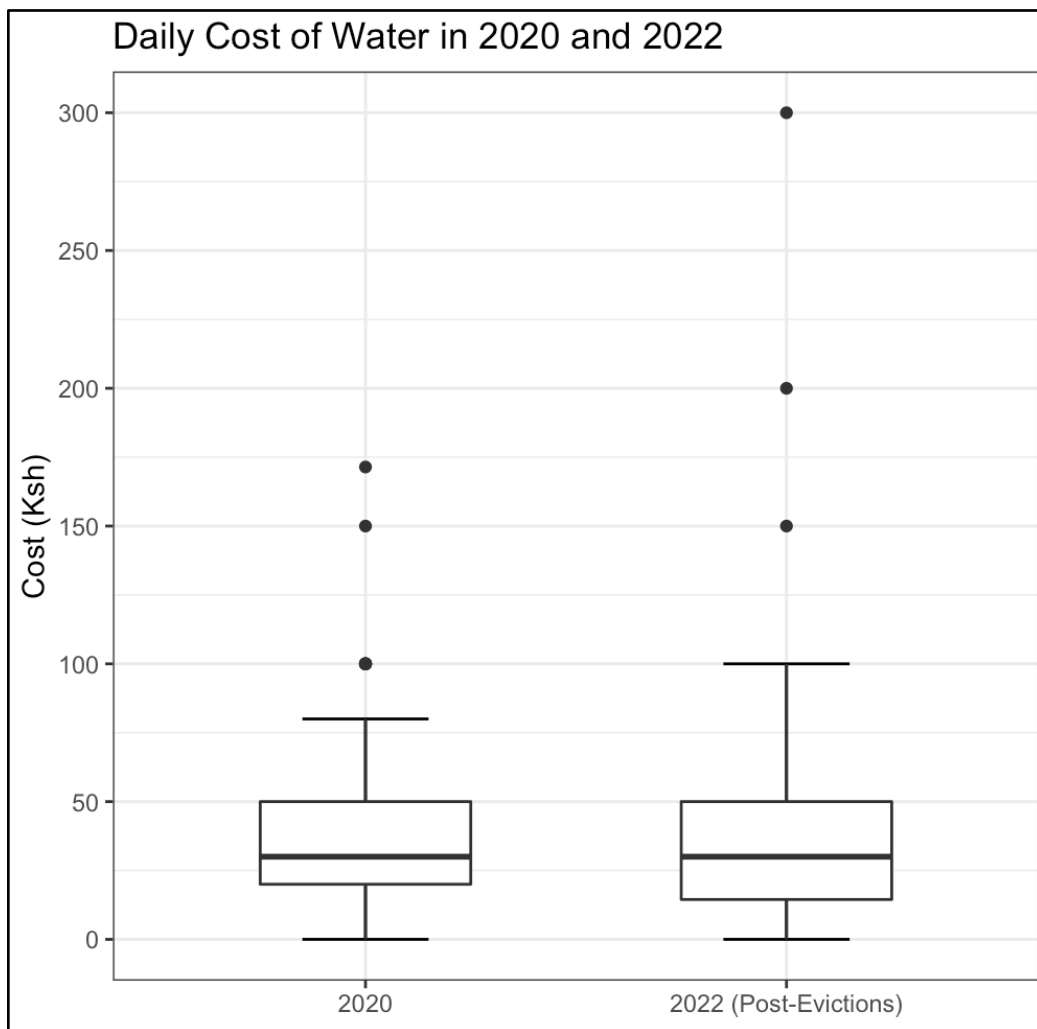


Figure C.4: Daily household expense on water pre- and post-evictions

Figure 5 shows the differences in time spent on collecting water by households during 2020 as compared to 2022 after the evictions. On average, households spent more time on collecting water after they were evicted.

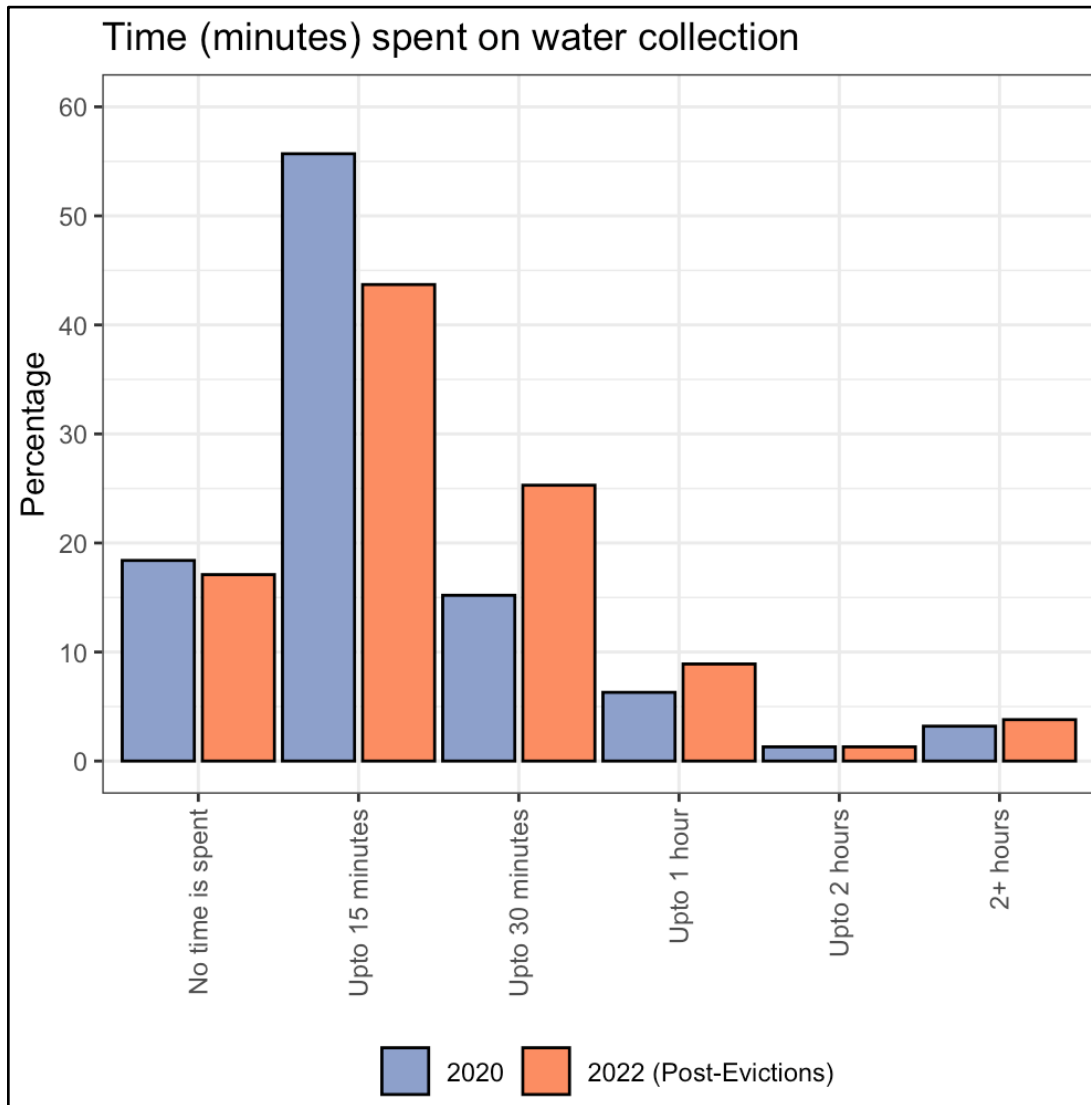


Figure C.5: Time spent on water collection pre- and post-evictions

C.7.3 Household water insecurity experience (HWISE)

We measured household water insecurity pre and post evictions by administering the 12 cross-culturally validated HWISE scale items (Young et al., 2019). However, we excluded one item - “In the last 4 weeks, how frequently has there been no usable or drinkable water whatsoever

in your household?" because it had 225 (>40%) missing values in the 2020 dataset. This was because, in our study sites, the meaning of "usable or drinkable" did not yield the same meaning that the question intended, which led to our respondents to respond "I don't know" or "not applicable" to this question. We learned from our enumerators that characterizing water as usable or drinkable led to confusion among respondents, since in our study site's context water can be usable, but not drinkable. This led our respondents to respond "I don't know" or "not applicable" to that question. Since >40% respondents had missing values (i.e., I don't know/not applicable) we excluded this question from our analysis.

Thus, our water insecurity score consisted of 11 items that queried the number of times in the past four weeks the household had experienced problems related to: (1) water availability [water supply been interrupted or limited, having to change plans due to unavailability of water]; (2) quantity [not enough water to wash clothes, having to change what is being cooked/eaten, no water to drink as much preferred, gone to sleep thirsty]; (3) safety [insufficient water for hand washing and bathing]; (4) psychological impacts [worrying about not having enough water, feeling angry, feeling excluded or stigmatized because of the water situation]. Each item had likert responses scored from 0 to 3 where 0 = never (0 times in the past four weeks), 1 = rarely (1–2 times), 2 = sometimes (3–10 times), 3 = often (11–20 times) or always (>20 times). Following Young et al. 2019 and Young, Collins, et al. 2019, we generated a score for each observation (household) by summing values across the 11 items, resulting in a range of 0–33, where higher scores indicate greater household water insecurity levels. This water insecurity index variable serves as a measure to test how different households fared in terms of water insecurity experience. We present the post-eviction data for water insecurity scores by eviction period because since water situation is fluctuating in the settlements, and our questions have a 4 weeks recall, so we

anticipate that January - September 2021 evicted households would fare differently on these indicators than households that were recently evicted between October 2021 - March 2022.

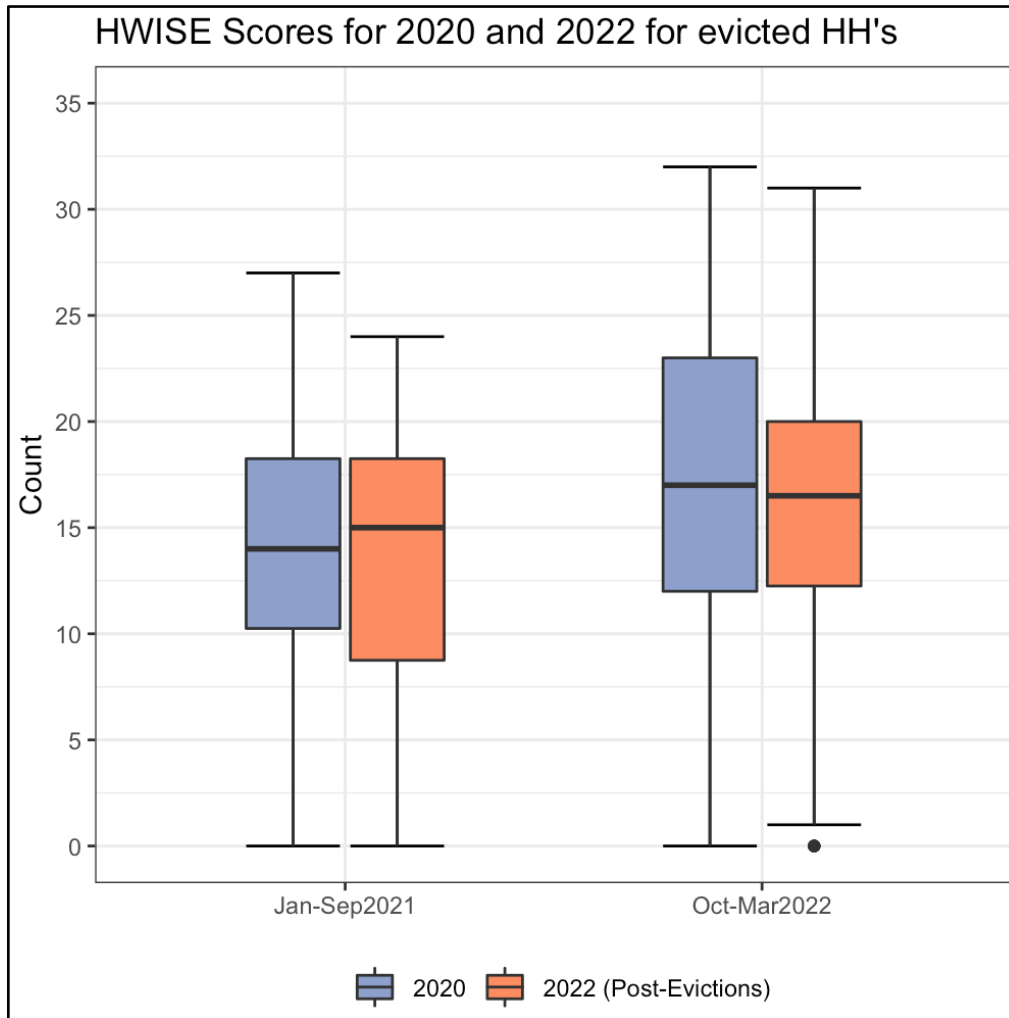


Figure C.6: Water insecurity levels pre- and post-evictions

C.8 Post-Eviction Losses, Aid and Movement of Households

We first started with asking households whether they knew why they were evicted, or their houses demolished. Even though business premises of Mukuru residents were also demolished, we only focused on house evictions.

C.8.1 Self-reported eviction reasons, notice of evictions, and humanitarian aid

Among the several reasons for why people were evicted, 63% of households reported that they were evicted due to road constructions in Nairobi. As one of our respondents explained, “They (Kenyan government) decided to build a road for the rich, and demolished our houses overnight.” Specifically, in the settlements of Mukuru Kwa Njenga, due to land disputes with industry giant Orbit Chemicals, many houses were demolished by the company. As such, 15% of our sampled households reported that they were evicted by a private landowner Orbit Chemicals. Nine percent of the households were evicted due to power line installations, 4% due to sewer line constructions, and 8% respondents weren’t aware of the reason for their evictions (Table 1). Among these evicted households, 33% (52 HHs) had lived in the house that was demolished for more than 10 years, 58% (92 HHs) had lived in their respective houses between 2-9 years, and 9% (14 HHs) had lived in their demolished houses for 1 or less years.

Table C.4: Reported reasons for evictions and evictions by study participants

Self-reported eviction reasons by households	Frequency (N)
Road Construction	100 (63%)
Land reclaimed by private owner	25 (16%)
Installation of power/electricity lines	14 (9%)
Sewer line construction	6 (4%)
Reason unknown	13 (8%)
Total	158 (100%)

One of the important rules of carrying out evictions for urban redevelopment is that the population evicted must be given an official notice of eviction, so that households can vacate the land to relocate at a rehabilitation site (Afenah, 2009; du Plessis, 2005; UN-Habitat, 2018). Therefore, we asked our respondents if they were informed or not, and if yes, by whom they were informed.

Out of the 158 households evicted, 75% claimed that they were not informed by anyone about the evictions, and only 25% of households (39 HHs) confirmed that they were informed about the evictions prior. Out of these 39 households that were informed about the evictions, only 8 households were informed by a government official or the local police chiefs in the area (20%). A majority of the households (49%) were informed either by a neighbor, friend, relative, landlord, or via community rumors, followed by 31% households confirming that a local NGO - Munganno wa wanavijiji informed them about the evictions prior.

Table C.5: Sources of information for households about evictions (N = 39)

Informing Entity	Frequency (N)
Neighbors, friend, relative, landlord, community rumors	19 (49%)
Muongano wa wanavijiji (NGO)	12 (31%)
Government official or local police chief	8 (20%)
Total	39 (100%)

A majority of the households reported not receiving any kind of financial help or assistance from anyone (91% HHs), whereas the remaining 9% households (14 HHs) reported having received assistance from the church, friends and relatives, NGOs, and 2 households reported getting help from a politician. The financial help ranged between 1000-8000 Ksh, where five households received between 1000-3000 Ksh, six households received between 5000-6000, and three households received between 7000-8000 Ksh. Other than financial aid, households reported getting help in kind from NGOs, churches, friends, and relatives in terms of food, water, utensils, bedding, tents, tin or iron sheets to rebuild from the losses.

C.8.2 Movement post-evictions

Households moved to a variety of different places within and outside of Nairobi after they were evicted. Out of the 158 evicted households, 69% households (110 HHs) moved within the three settlements and 18% (29 HHs) came back to the same location where their house was located before evictions (no change in location). As such, 87% of the households (137 HHs) moved within the settlements. Figure 9 shows the movement of households after the evictions occurred.

When we asked these households about the reason for their decision to stay within the settlements despite the safety concerns, respondents gave one of the following reasons - it was affordable for them, they were born and brought up in Mukuru settlements and had nowhere else to go, and that they were closer to facilities like children's schools, shops, and had a social circle that they did not want to leave.

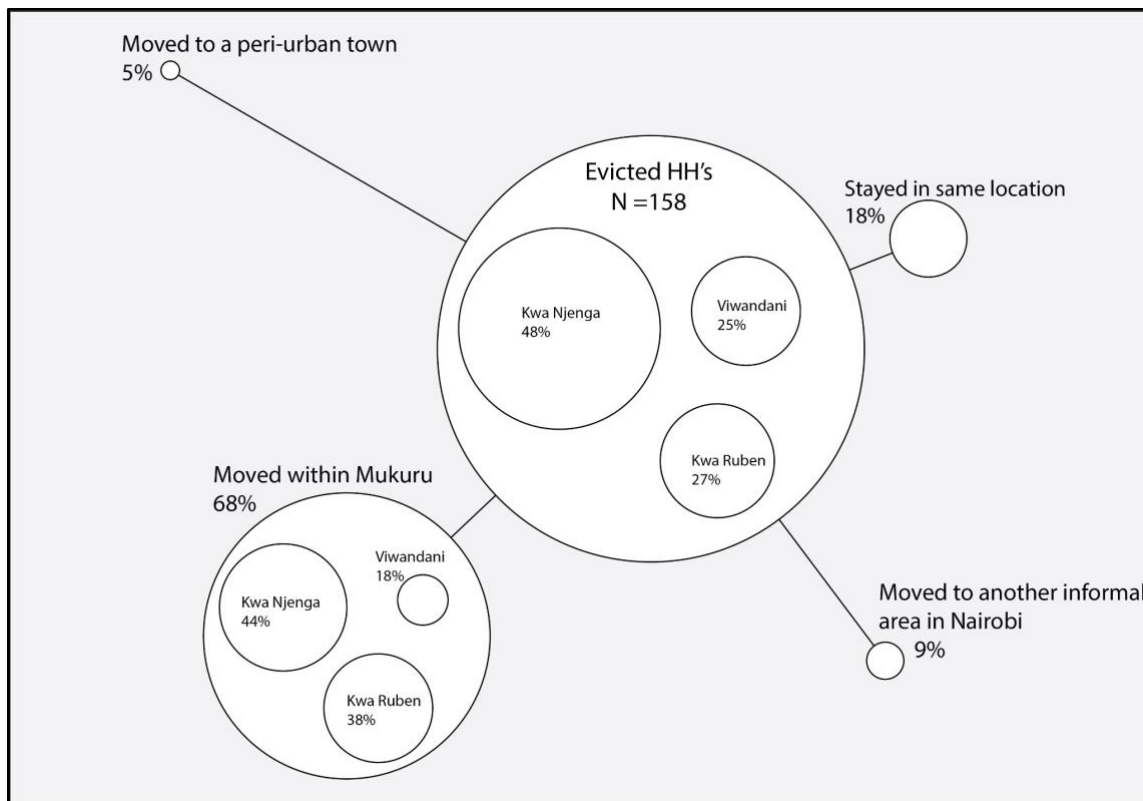


Figure C.7: Movement of households' post-evictions (N=158)

Even the 14 households (9%) who moved to other informal settlements in Nairobi, these settlements were within 5 miles of Mukuru settlements. The informal areas that households relocated after evictions were in Pipeline (5 HHs), Umoja estates (3 HHs), Imara estates south of Mukuru Kwa Njenga (2 HHs), Quarry informal area (2 HHs), Kayole (1 HH), and Makadara (1 HH) - all a part of the larger Nairobi Metropolitan region. When we asked these households the reason for moving to other informal settlements, respondents gave two main reasons - they thought that these places would not get demolished and felt temporary safety there, and/or they had relatives or a friend in these places. Figure 3 maps the eight informal settlement areas where the 14 households moved to after they were evicted.

Only 7 households (4%) moved to small pre-urban towns far away from Nairobi. These households moved to small towns in Kakamega (2 HHs), Kisii, Kilifi, Embu, Machakos, and Kiambu counties (remaining 5 HHs in each county). When we asked these households the reason for moving to these peri-urban places outside of Nairobi, households gave two main reasons - they had relatives in these places or they were returning to where they originally migrated from.

C.9 Discussion

Our findings highlight that tackling the underlying causes for informal settlement formations and providing suitable rehabilitation to the evicted households must be prioritized, failing which the evicted community often returns to the same informal settlements or resettles in new informal areas. In addition, forced evictions are an added vulnerability to the already struggling informal settlement households during a global pandemic (Joshi et al., 2022; Wasdani & Prasad, 2020). Despite these already existing vulnerabilities, even after the households were evicted we show that a majority of households settle back into the same areas or form new slums elsewhere. Out of the 158 households that were evicted either due to infrastructure upgrading or

major road construction, 137 households (87%) came back to live in one of the three settlements. On asking why these households came back despite the added risk of eviction, households expressed that more than the risk of getting evicted again, they cared more about being close to their children's schools, being able to afford living, and being where the surroundings were familiar. Similarly, those households that moved to nearby informal settlements (9% HHs), expressed that being nearby Mukuru settlements gave them access to their social networks and other basic necessities. The nearby areas of Kayole, Pipeline, Umoja estates, Kware, Imara, Makadara, Quarry, and Tassia estates, where the households relocated, are equally at risk of being evicted as they are informal. The basic services in these areas are as poor as in Mukuru settlements (Satterthwaite et al., 2020). Therefore, even though some households moved here, they lacked security. This has trapped informal settlement residents in insecurity cycles, where they are evicted due to lack of land and housing tenure, without compensation or safe relocation, to only have them settle back in other informal areas that are ridden with the same issues (Bouwmeester & Hartmann, 2021; Muchadenyika, 2015; Muchadenyika & Waiswa, 2018). These patterns of haphazard development plans that evict informal settlement households, do not really solve the structural issues of land and resource distribution in a city (Asiama et al., 2021).

Housing tenure is one of the important pathways through which other essential services like water supply can be improved (Gulyani et al., 2018; Joshi et al., In review). Between 2020 and before the households were evicted, tenure status improved by 10%. As such, in 2020, 98% of the sampled households were tenants whereas this number reduced to 88% before the evictions occurred - 12 households converted their tenancy into home ownership prior to getting evicted. In contrast, after the evictions, only 2 out of these 12 households were able to resettle back into houses they owned, whereas other households (98%) resettled in rented houses shared with other

households, and temporary tents. Furthermore, the pandemic combined with the evictions pushed households into precarity where we show that the median rents that households paid after the evictions rose up from Ksh 2000 to Ksh 2500 after the evictions. While the change of Ksh 500 may not seem large, given the pandemic-related shocks, coupled with evictions, a 500 Ksh raise could cripple households to fulfill other needs such as food, sanitation, and education.

In terms of water access, the percentage of households that accessed formal services after the evictions increased after the evictions. In 2020, only 3% (5 households out of 158) accessed formal water sources whereas, after the evictions, 29% households reported using formal water services for their household water needs. This increase in formal service access may have been due to Nairobi Metropolitan Services (NMS) efforts in late 2020 to help informal settlement households access water in the wake of the pandemic. Specifically, the NMS has installed several boreholes and water kiosks that supply water to households for free (Kimatu, 2021; Omulo, 2021), which may be the reason for improved formal access to water despite the evictions. The remaining 71% of households still used informal water services after the evictions. Surprisingly, the average cash spent on water on a daily basis did not change much - 37 Ksh in 2020 and 35 Ksh after the evictions, however, the range of the expenditure became wider. While households were paying between ~ 37-170 Ksh in 2020, this range changed to ~ 35 - 300 Ksh after the evictions. This is concerning given that households were already dealing with the stressors of being evicted and the COVID-19 pandemic. In addition, the collection time significantly went up. While a majority of the households spent up to 15 minutes collecting water in 2020, this collection time had changed to 30 minutes - 1 hour for many households after the evictions. Given these findings, it was surprising that the median water insecurity levels of households that were evicted between January 2021 and September 2021 were higher, whereas for those households that were evicted between

October 2021 and March 2022, their household water insecurity levels remained almost the same as their levels in 2020. This may have been because of the humanitarian aid that households received in the second drive of evictions. Overall, while water services improved from informal to formal with a larger percentage of households accessing formal sources, other indicators such as cost of water, collection time, and water insecurity, did not show any improvement.

We were unable to compare household income and wealth indices pre and post evictions. This was because our unit of analysis was a household, and because the evictions split and dispersed households, to living with multiple other households, or in tents, it was not possible to compare these exact income and wealth indicators. However, we believe that given the informal settlement context, income and wealth is fluctuating, and housing tenure, rent prices, and water security might be a better way to measure the before-after situations. In addition, validated food and water security matrices do not capture the impacts of evictions well in terms of the timeline. For instance, evictions are usually slow and ongoing, however, metrics such as the reduced coping strategy index (RCSI), food insecurity experience scale (FIES), household water insecurity experience scale (HWISE) have recall period of past 7 days or 4 weeks, and if the evictions happened 2-3 months prior, it is not possible to capture the ongoing impacts of evictions. In addition, during evictions, households receive different kinds of aid and help from humanitarian organizations, and these scales do not account for these interventions, and how they improve or worsen the security of evicted households. Future studies could develop scales to measure impacts of evictions. While there has been a lot of work done to measure impacts of floods, droughts and other natural disasters on urban households, a standard metric to measure the impacts of evictions is important to take the field of urban studies forward. We also acknowledge that we may be underrepresenting the actual hardships of evicted households and the actual number of evicted

households from our initial sample of 540 households. We may have been unable to contact many evicted households because we were unable to reach many households. When contacted, 11 households denied participation as they had become homeless due to the evictions. In addition, around 100 households from our previous data collection sample were unreachable. Therefore, we recognize that the evicted households that we surveyed might have been able to cope after the evictions than others that we were unable to contact. Our results may have underestimated the actual changes that occurred in the settlements after the evictions.

This research shows that forced evictions only temporarily displaced residents of Mukuru settlements given that they relocated to other nearby areas with similar informal housing status. But this displacement imposed a significant hardship on households with commensurate impacts on housing and water security as well as fundamental disruptions for the households that already struggled to meet daily basic needs. Urban processes that displace residents of informal settlements should take into consideration the stability of housing, water and food security in helping households buffer the negative impacts of displacement. In addition, urbanization and population growth intensify the negative impacts of these changes on the urban poor by making basic services such as housing, water, sanitation, electricity, and employment opportunities inaccessible. Therefore, as urban population grows in cities of sub-Saharan Africa, eviction issues must be dealt with in regard to human rights and in a way that serves the urban poor.

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