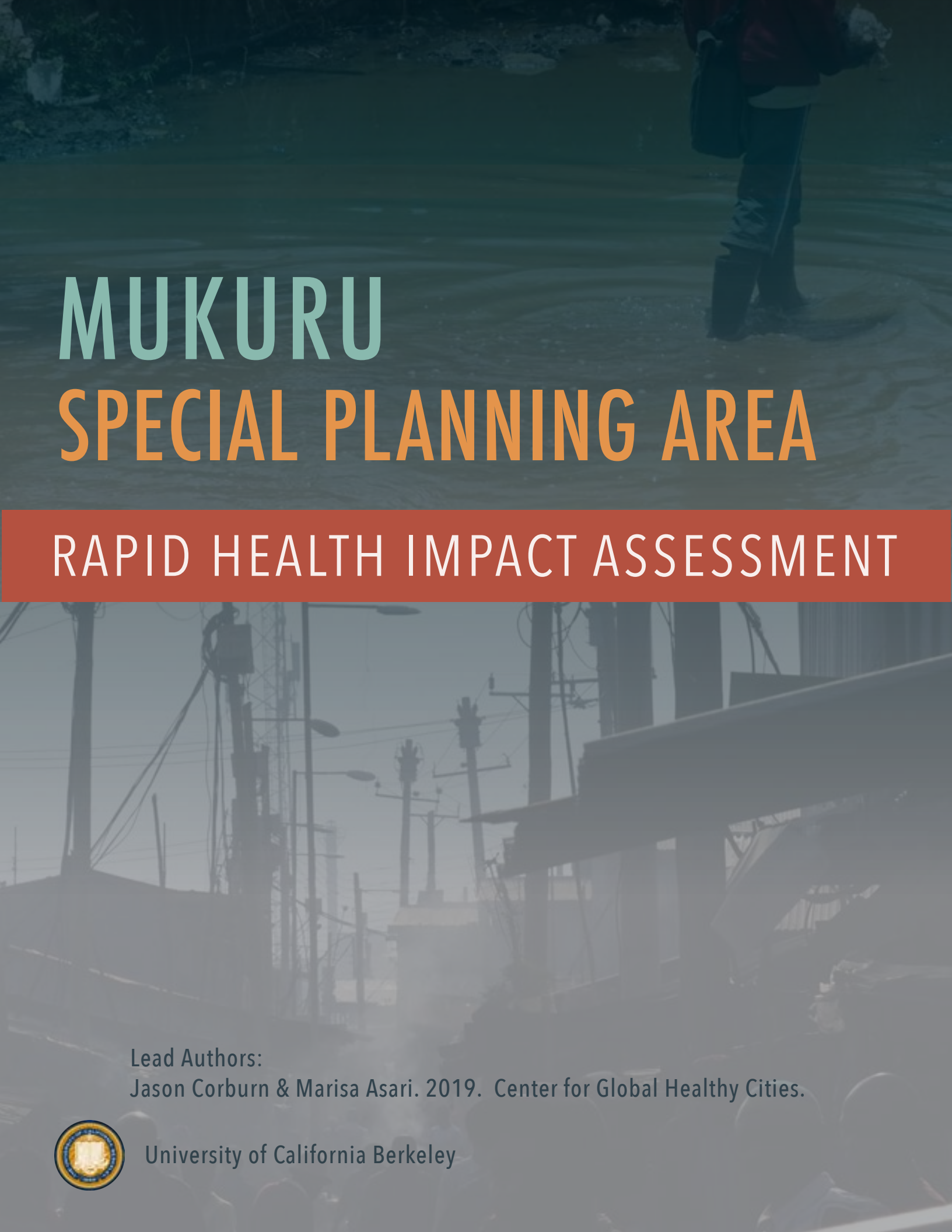


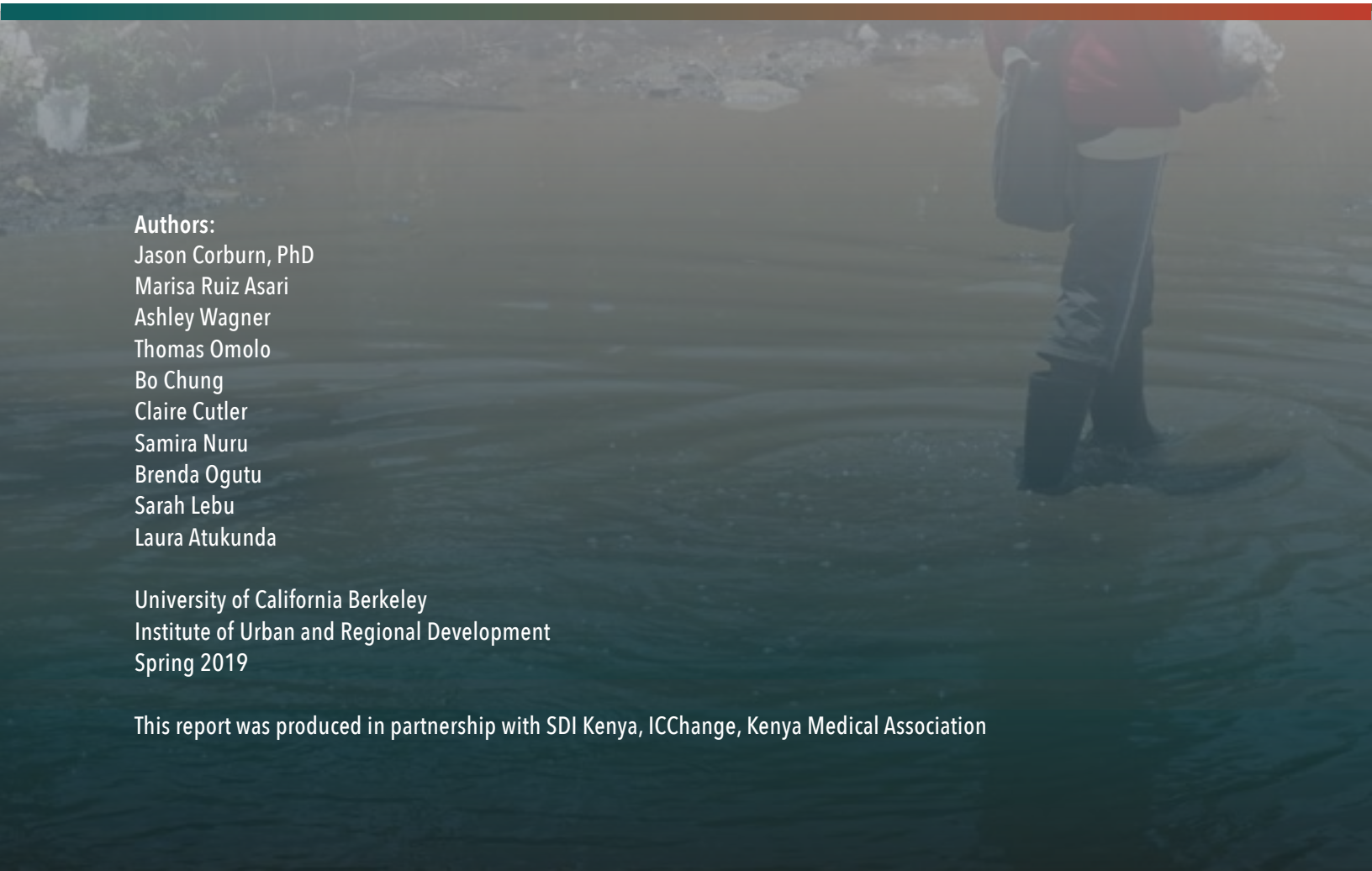
MUKURU
SPECIAL PLANNING AREA

RAPID HEALTH IMPACT ASSESSMENT

Lead Authors:
Jason Corburn & Marisa Asari. 2019. Center for Global Healthy Cities.

University of California Berkeley

MUKURU SPECIAL PLANNING AREA
RAPID HEALTH IMPACT ASSESSMENT



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Spring 2019

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EXECUTIVE SUMMARY

In 2017, the Mukuru informal settlement in Nairobi, Kenya, was declared a Special Planning Area (SPA) due to its unique environmental, health and development challenges. The SPA designation prevents development for a two-year period, requiring that the Nairobi City County government develop and adopt an integrated improvement plan for the area by August 2019.

This Rapid Health Impact Assessment (RHIA) aims to support the SPA planning process by assessing the health impacts of existing conditions and potential planning interventions.

The purpose of this RHIA is to:

1. Link data on existing environmental conditions in Mukuru to potential human health impacts.
2. Address key health concerns raised by the Mukuru community.
3. Develop clear and actionable environmental health pathway diagrams.
4. Offer key indicators to measure and track the impact of any future interventions, particularly those emerging from the SPA, on the health and well-being of Mukuru residents and all people living in that region of Nairobi.

The analyses in this report focuses on the following key environmental health risks identified through community consultations as key concerns: industrial hazards, soil contamination, flooding, food contamination and poor sanitation.

KEY FINDINGS

Industry & Built Environment

- There are over 1,000 industrial sites surrounding Mukuru
- Hazardous pollutants include Particulate Matter (PM), Volatile Organic Compounds (VOCs), and Heavy Metals, including lead.
- Industrial effluent and air pollution is released into the community from surrounding industries.
- 19% of residents surveyed experienced coughing symptoms in the past 6 months.
- 43% of households reported cough being a top reason for visiting a healthcare provider in the past 6 months, making this the most common reason for visits.
- Children are particularly vulnerable to industrial pollution, including lead poisoning.

Flooding & Soil

- Over 2,000 structures are at risk of flooding in the Ngong River Riparian.
- About 7,500 structures may be at risk of flooding in the case of an extreme flooding event.
- 27% of households surveyed reported experiencing flooding in the past six months.
- Households that reported flooding in Mukuru in the past six months were more likely to report that a health issue impacted a family member during the same period.
- 34% of households that experienced household flooding reported headache as a top reason for visiting a healthcare provider in the past 6 months compared to 18% of households that did not experience flooding.

Sanitation & Nutrition

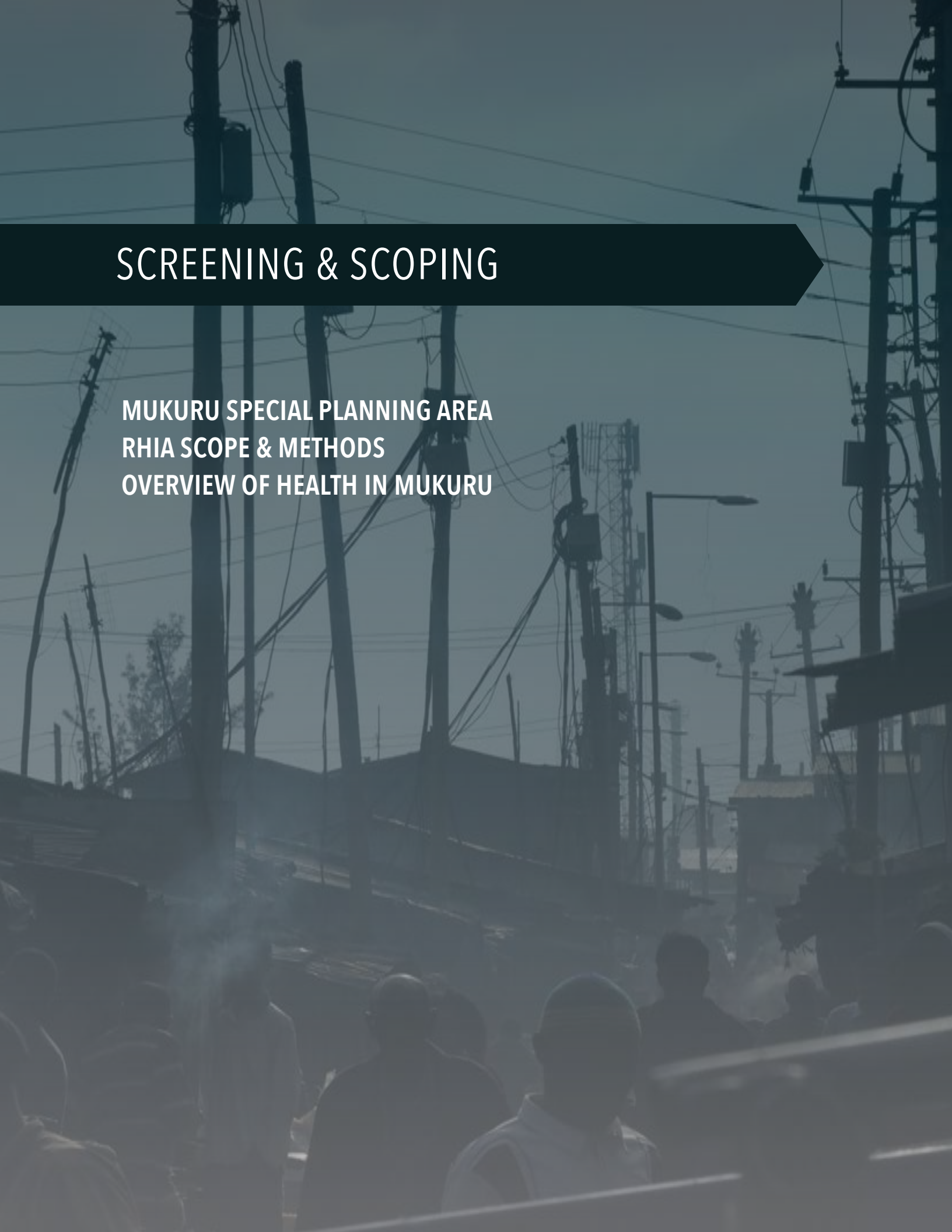
- 33% of households in Mukuru are likely food insecure.
- About 12% of Mukuru households lack adequate food on a daily basis.
- Less than 1% of households have access to a private in-home toilet as their main sanitation option
- About 17% of households without regular waste collection report diarrhea as a reason for visiting a healthcare provider in the past 6 months.
- Of households reporting that they purchase water from vendors, 18% had diarrhea in the past 6 months.
- Residents pay over three or more times for inadequate toilets and water than those living in formal areas of Nairobi.
- Some households spend up to 70% of their income on food and sanitation (mostly toilet use fees).
- Children are particularly at risk for sanitation & nutrition related illnesses including diarrhea and stunted growth from lack of nutrient absorption

Key Recommendations

The Mukuru informal settlements are adjacent to a number of environmental health risks including industrial hazards, air pollution, soil contamination and dangerous flooding. These environmental hazards combine to make some areas and populations in Mukuru especially vulnerable. Any development plan for the community must consider the following:

- A comprehensive development-specific environmental health impact assessment.
- Soil analyses to ensure lead and other metals are not present.
- A remediation plan to reduce and eliminate environmental risks.
- A specific flooding mitigation plan that includes retention walls, diversion and other technologies.
- Consideration of a flood-zone where development of housing, schools and other sensitive land uses are restricted to protect residents.
- Development of flood and climate change resilient infrastructure, such as roads, drainage, bridges and public safe spaces that are elevated and able to withstand large rain and flooding events.
- Engagement with neighboring industries to develop a toxic use reduction plan.
- A strategy to capture, regulate and treat all industrial effluent into the water, soil and air.
- A community-monitoring plan, to ensure local residents co-create and participate in the monitoring of current and future environmental health hazards.

This report is intended to support the on-going processes and evidence base of the Mukuru Special Planning Area (SPA). Ultimately, we hope these data contribute to interventions and strategies that improves the health and environmental conditions for residents of Mukuru and all those living in Nairobi.



SCREENING & SCOPING

MUKURU SPECIAL PLANNING AREA
RHIA SCOPE & METHODS
OVERVIEW OF HEALTH IN MUKURU

The Mukuru Informal Settlement

Mukuru is one of the largest of over 150 informal settlements in Nairobi, Kenya. Mukuru has over 100,500 households and an estimated population of 300,000 people. The Mukuru area includes the settlements of Mukuru Kwa Njenga, Mukuru Kwa Reuben, Viwandani, Mukuru Kayaba, Fuata Nyayo, and Mariguini, which are situated in an industrial zone approximately seven kilometers southeast of Nairobi's central business district.

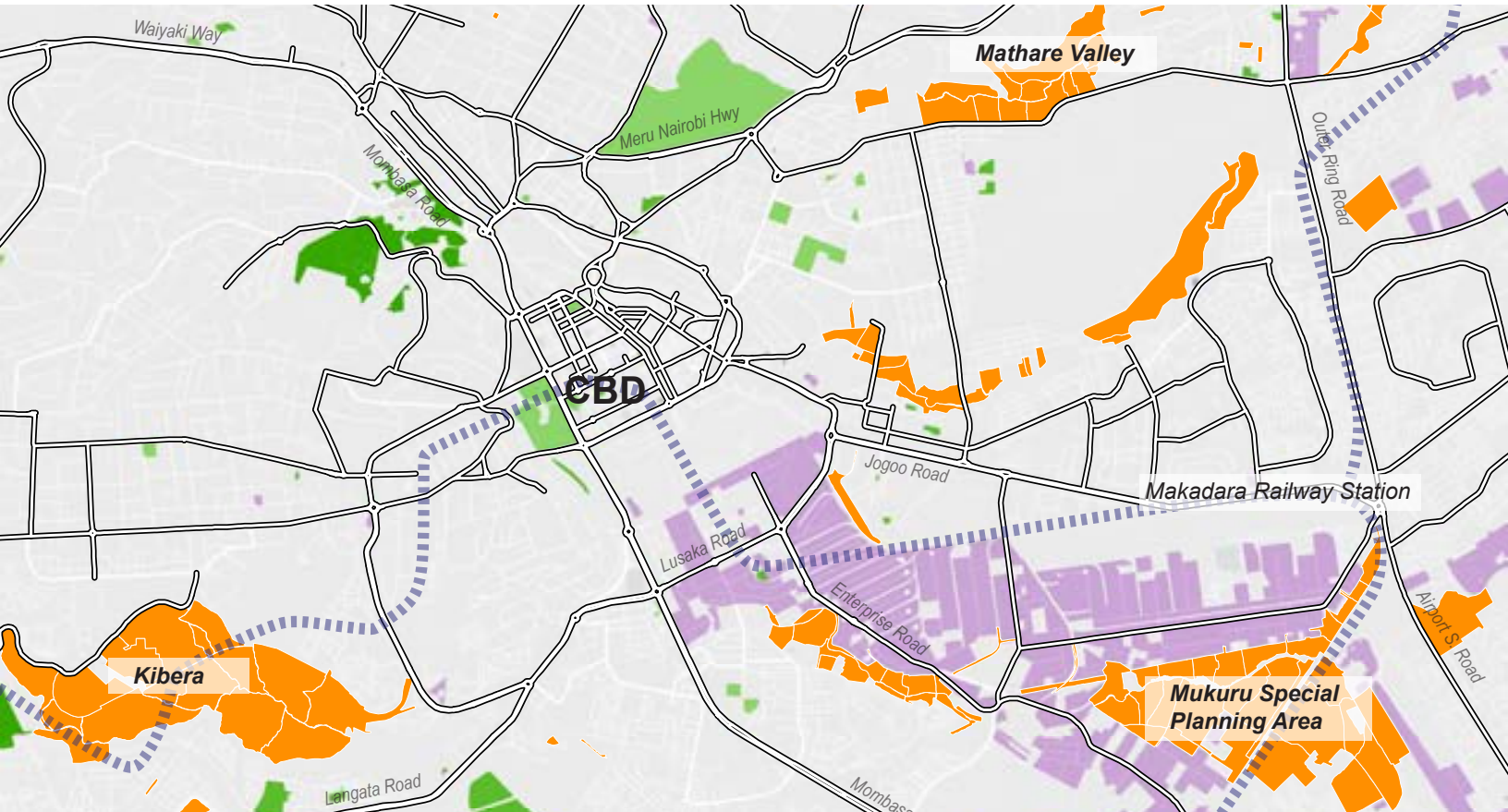
Despite a previous transfer of land titles to private developers in the 1980s, the land in Mukuru remained undeveloped and was settled upon by migrant families and industrial workers drawn to jobs in the neighboring industrial area and Nairobi's city center. As the settlements began to grow and densify, issues of land tenure and threats of eviction intensified the contestation of land ownership in Mukuru.

Environmental Health & Equity Concerns

The land tenure issues and controversies in Mukuru contributed to the area being largely excluded from county and national planning initiatives as well as investments of formal governance systems and services. This lack of planning and investment contributed to the present-day conditions in Mukuru of rapid, haphazard, often unsafe development with a lack of basic services.

The absence of services such as drainage, sanitation & waste management combine with Mukuru's proximity to industrial activities to pose cumulative environmental health risks for residents. We found that lack of solid waste management and sanitation along with the dumping of industrial waste into the Ngong River expose residents to a plethora of hazards during frequent floods. These flooding and

Map 1 Mukuru SPA, Nairobi, Kenya



exposure events are becoming more severe, with more significant disease burdens, due to climate change induced weather.

Results from our 2018 Mukuru Household Health Survey found that 37% of households in Viwandani and 43% of households in Mukuru Kwa Njenga had no regular waste collection. Only 3% of households in both areas had a water connection inside the home.

The majority of households surveyed were informally employed, and 13% of households reported that their head of household was unemployed. The survey also found a disproportionate number of female headed households. In Viwandani, 61% of households had a female house of head, with this figure slightly lower in Mukuru Kwa Njenga, at 57%. Informal employment, job insecurity, and gender inequity contribute to cyclic poverty, and make coping with environmental risks an even greater challenge.

While Mukuru faces many challenges, it has strong community assets such as women-led savings groups, youth leaders, a network of schools and community facilities, and a robust informal labor market that provide opportunities for growth and are already contributing immensely to the economy and social fabric of Nairobi. The ongoing work in Mukuru has engaged these community stakeholders and utilized settlement profiling, a community-led action research process, to gather and compile information in the following areas: access to land (eviction); access to services (water and sanitation, electricity, health, education, and nutrition); livelihood opportunities; and demand for housing, infrastructure, and planning. Data collected at the structure level across the 100,561 households in Mukuru is spatially linked, and further analysis has allowed the research team to visualize each of the data sets through mapping exercises that profile the settlement.

The Mukuru Special Planning Area

In 2017 Muungano wa Wanavijiji, SDI, AMT, the Mukuru community & academic partners together submitted evidence to have Mukuru declared a Special Planning Area (SPA) by Nairobi County government. The SPA designation requires that planners and community members develop an integrated plan to improve both immediate and long-term issues in the area, including infrastructure, environmental and health challenges.

The outcome of the SPA process will be an Integrated Development Plan adopted by Nairobi City County for improving living conditions for all of Mukuru and the surrounding area by August 2019.

Figure 1 Key Goals of the Mukuru Special Planning Area

RHIA Scope and Methods

Health Impact Assessment Tool

Health Impact Assessment (HIA) uses a combination of procedures, methods and tools to analyze the potential, and sometimes unintended, effects of a policy, plan, program or project on the health of a population and the distribution of those effects across population groups. HIA is a process that aims to create healthier communities by providing decision-makers with an understanding of the potential health impacts of a proposed project, and makes recommendations that could reduce adverse impacts. The purpose of conducting an HIA is to inform stakeholders and decision-makers about the population health implications of proposed actions, to identify and examine trade-offs, and to encourage the exploration of health promoting alternatives.

A Rapid or sometimes called a "desktop HIA", does not include the extensive community and stakeholder input of a typical HIA. Instead, the Rapid HIA (RHIA) utilizes existing data and limited stakeholder engagement to generate analyses that can inform ongoing policy debates and identify areas for additional study. The key stages of the HIA process are highlighted in Figure 2, and this RHIA includes the first three major steps of screening, scoping & assessment. While there is no single best approach to HIA, each HIA process should reflect the needs of its particular context. An HIA is most often carried out prospectively, before a decision is made to enact a policy proposal. This RHIA seeks to support the ongoing Mukuru SPA planning process rather than assess an existing policy or plan, and to inform community decision making around environmental and health risk reduction strategies that may be adopted to protect the well-being of Mukuru residents.

Methods

The Mukuru RHIA utilizes household health survey data as well as secondary sources and studies to assess the impact of industry, flooding, and sanitation & nutrition on health in Mukuru. Primary data comes from the 2018 Mukuru SPA Household Health Survey, conducted collaboratively by SDI Kenya, ICChange, Kenya Medical Association and others. We provide an overview of the survey results categorized by symptom on pages 11-16. Additional data and findings build off of a 2017 SPA Situational Analysis report and the collaborative work of planning consortia members including Strathmore University and University of Nairobi.

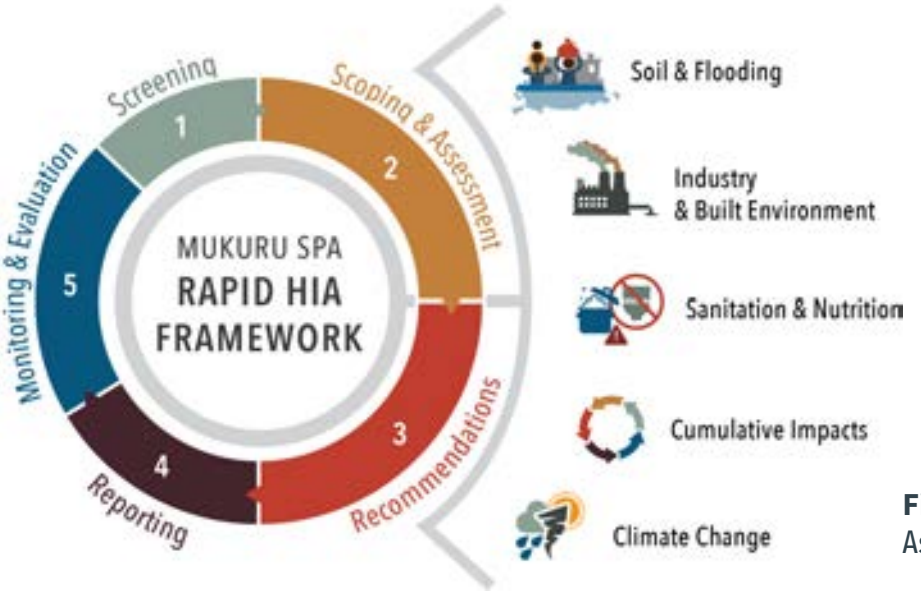


Figure 2 Rapid Health Impact Assessment Focus Areas

Overview of health in Mukuru: 2018 Household Survey Key Findings

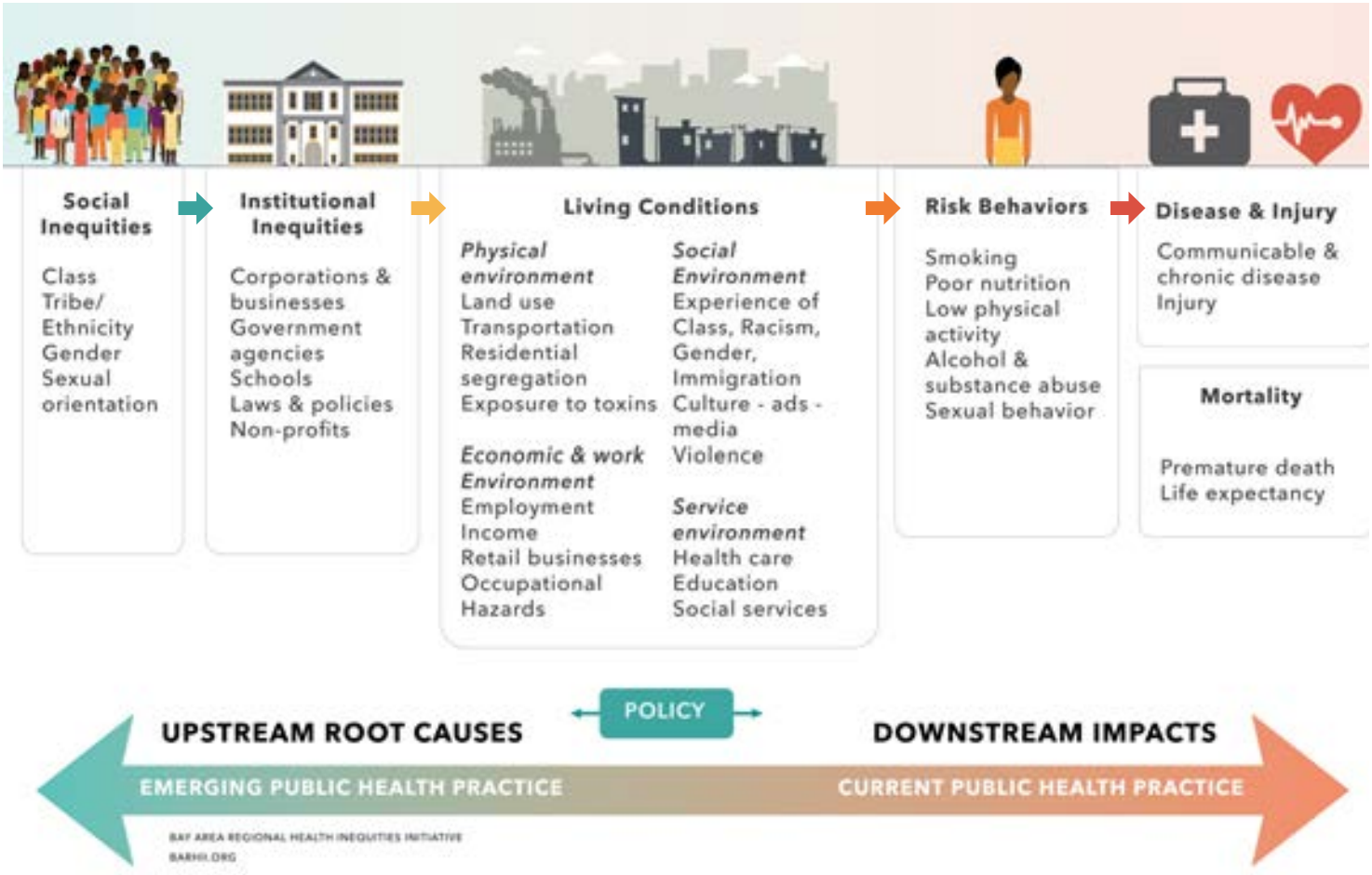
The 2018 Mukuru SPA household health survey sampled a total of 368 households in Mukuru Kwa Reuben and Viwandani, with 1,439 individual respondents (household members). The survey asked a series of household level questions on living conditions and health determinants including access and quality of sanitation, water, healthcare, and housing among others. Household heads were also asked about employment status, perception of family health, common reasons for family visits to healthcare facilities, and priorities for improving community health.

At the individual level, the survey asked a series of questions about the health and wellbeing of each household member. This section of the survey focused on symptoms experienced within the last six months, as well as any reported disability or diagnoses of illness.

368 Households
1,439 Individuals

Sampled in the Health Survey

Figure 3 Framework for Health & Place in Mukuru



The analysis summarized in this report takes a two pronged approach by, 1. comparing household living conditions with reported reasons for family visits to a healthcare facility in the last six months, and 2. linking symptoms experienced by individual household members in the last six months to household level living conditions. The analysis takes an equity approach and aims to identify vulnerable populations by focusing on a series of demographic indicators and subgroups such as age, gender, employment status, and size of household.

General health & healthcare key findings:

- The most frequently reported priorities for improving health were 1. improving toilets, 2. improving drinking water, 3. increasing level of knowledge about hygiene, 4. improving drainage and reducing flooding, and 5. increasing clinics. However priorities varied significantly by settlement, as well as gender and employment status of household head.
- 42.7% of households report that their family visited a health facility more than once in the last 6 months.
- 26.9% of households report that their family visited a health facility 3 or more times in the last 6 months.
- The most common reported symptoms and reasons for visits to a health facility in the last 6 months were cough, chest problems, diarrhea, fever, and headache.
- 39% of households report that their family is in poor or fair health, and 44.6% of households report that health issues have impacted a family member in the last 6 months.
- 27% of households report experiencing flooding in the last 6 months, and 57% of those households report that health issues have impacted a family member during the same period, compared to only 40% of households that did not experience flooding.
- 72% of households pay out of pocket for health care services, 30% access care through the National Hospital Insurance Fund (NHIF).
- 28% of households pay more than 800Ksh per health care visit, which may represent a high monthly household expenditure compared to income.
- 69% of households report that cost is a barrier to accessing care when they are sick, 31% report that distance is a barrier.
- 73% of households walk to reach their health facility; 44% of all households report that it takes them between 30-60 minutes to reach the health facility, and an additional 21% report that it takes them 1-2 hours.

Health equity - who is most vulnerable?

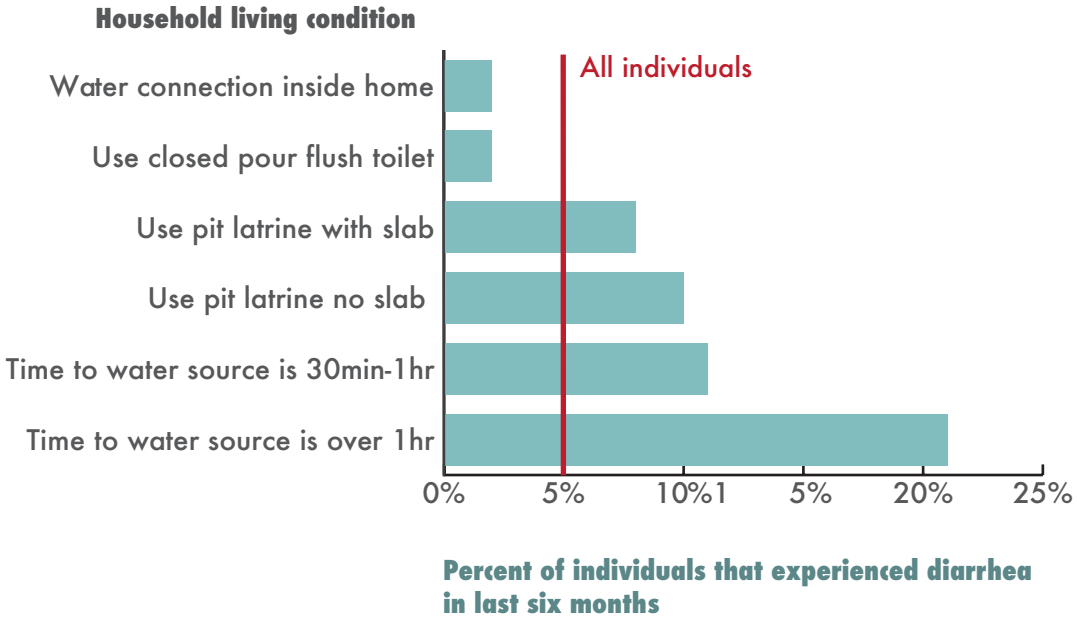
- 65% of female headed households report seeking treatment at a public hospital, compared to 55% of male headed households. Only 38% of female headed households report seeking treatment at a private hospital, compared to 50% of male headed households.
- A greater percentage of female headed households reported cough and chest problems as a top reason for seeking care compared to male headed households. A higher percentage of male headed households reported fever and headache as a top reason for seeking care.
- Households with an unemployed head reported cough, chest problems, and headache as top reasons for seeking care at higher rates than those with employed household heads.
- 10% of children ages 0-4 experienced diarrhea in the last 6 months compared to only 4% of individuals 5 years or older.

SYMPTOMS & HOUSEHOLD LIVING CONDITIONS

DIARRHEA

5% of individuals experienced diarrhea in the last six months, and 14.4% of households reported diarrhea as a top reason that a household member visited a health facility in the same period. The percentage of individuals that experienced diarrhea dropped to 2% for those who have water connections in their home and those who use a closed pour flush toilet as their main sanitation option. A higher percentage of those who use pit latrines and who have extended time to nearest water source (more than 30 minutes) report experiencing diarrhea compared to all respondents. In addition, a higher percent (10%) of children between 0-4 years old experienced diarrhea compared to all other age groups.

Figure 4
Diarrhea & select living conditions



FEVER & HEADACHE

12% of individuals experienced fever in the last six months, and 36.4% of households report fever as a top reason that a household member visited a health facility. Within the same period, 11% of individuals experienced headache, and 23% of households reported headache as a top reason that a household member visited a health facility.

Use of VIP toilets and pit latrines were associated with higher reported fever and headache. Individuals whose households are between 30 minutes to one hour away from their water source and those that experienced flooding in the last 6 months were also more likely to report experiencing headache.

Figure 5
Headache & select living conditions

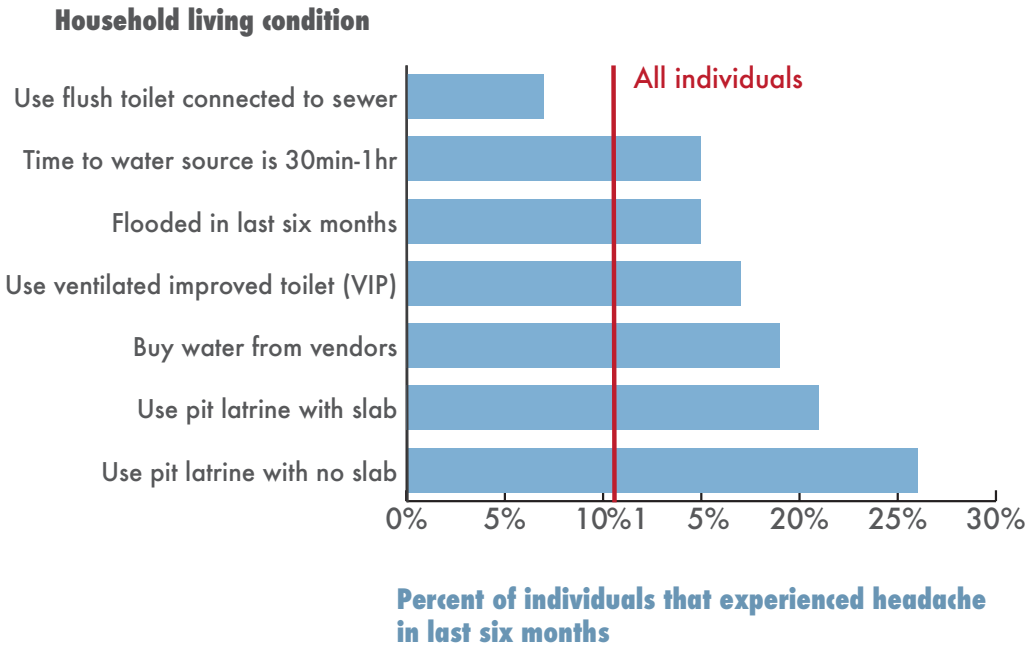
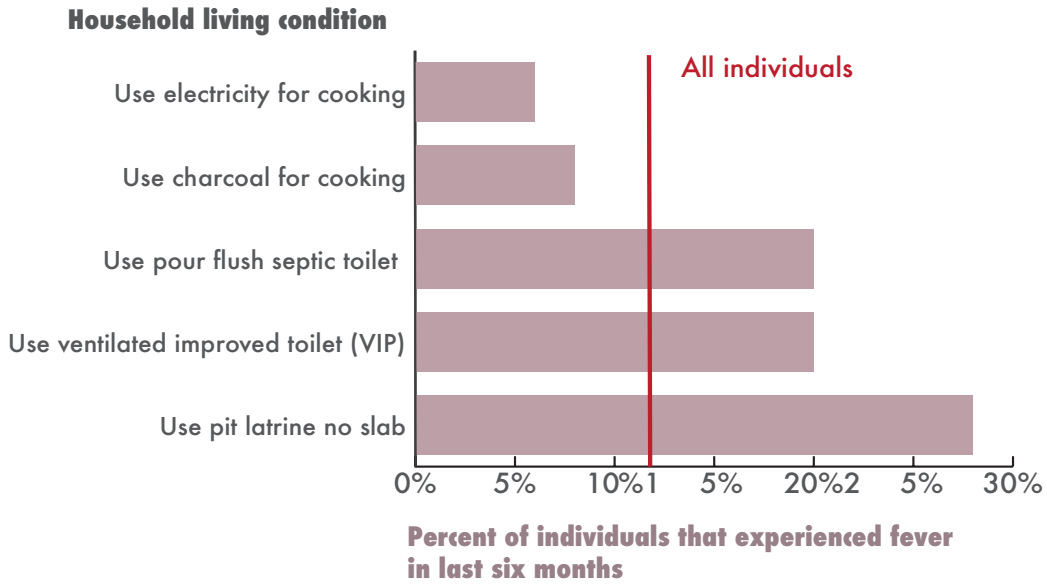


Figure 6 Fever & select living conditions



COUGH & CHEST PROBLEMS

19% of individuals experienced cough in the last 6 months, and 43% of households report cough as a top reason that a household member visited a health facility in the last 6 months. 5% of individuals report experiencing chest problems in the last 6 months, and 12% of households report chest problems as a top reason that a household member visited a health facility in the last 6 months. Safer options for sanitation, water and cooking were associated with lower percentages of both cough and chest problems, and conversely poor access or quality of these resources were associated with increased reporting of the same symptoms.

Figure 7 Cough & select living conditions

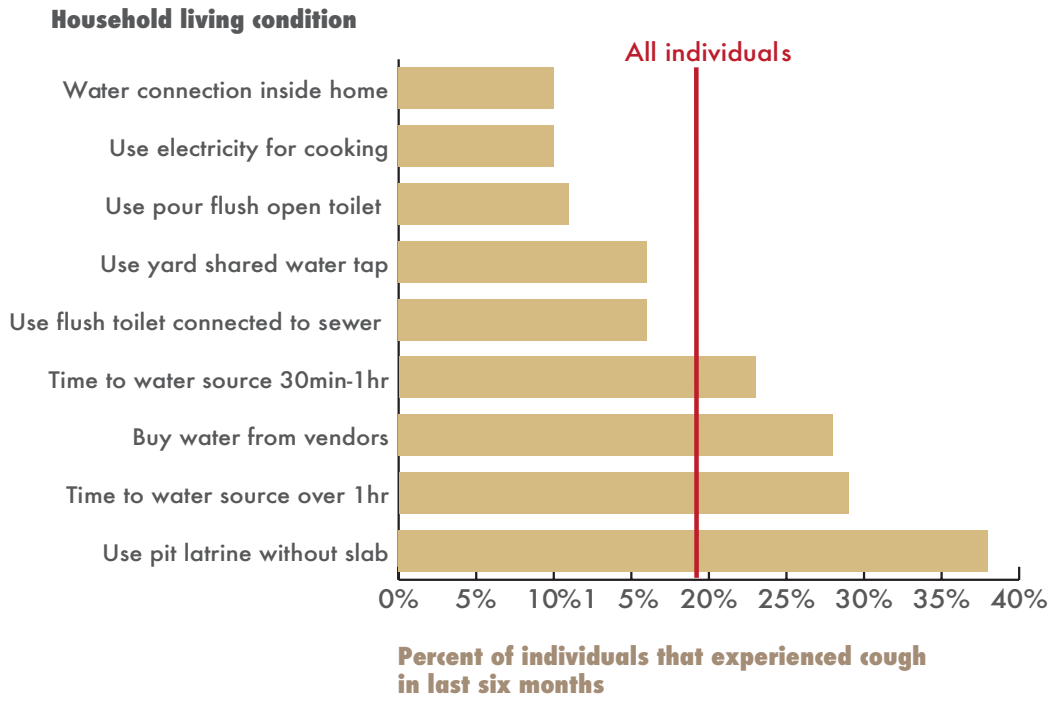
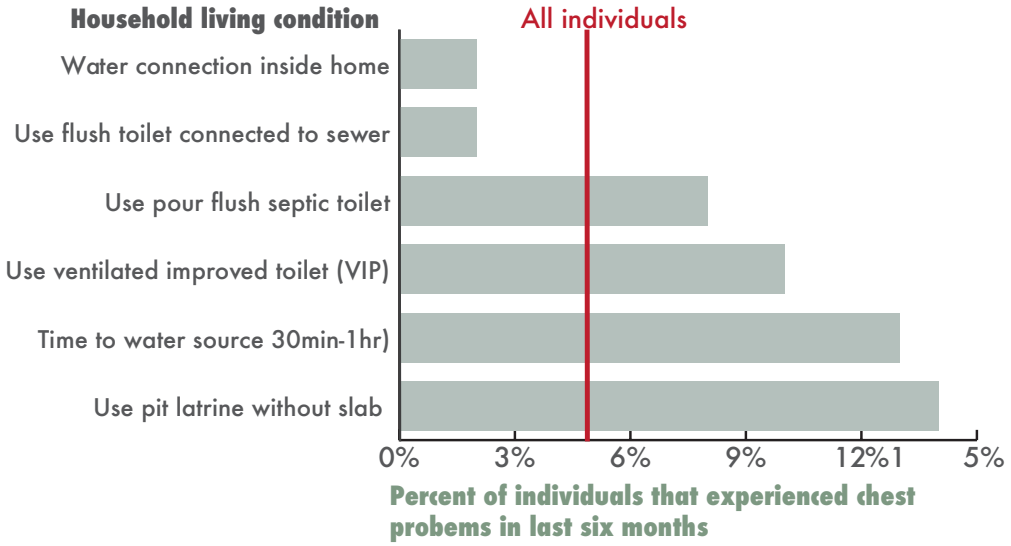


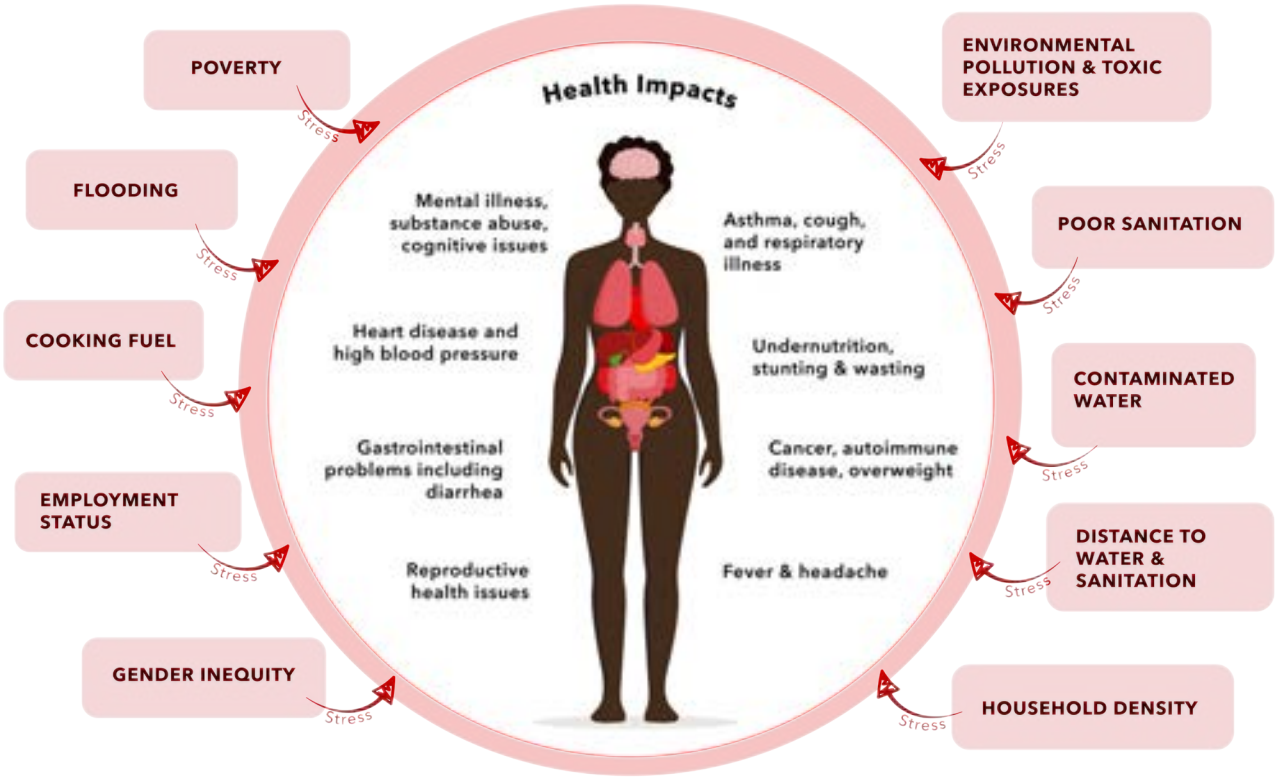
Figure 8 Chest problems vs. select living conditions



Toxic Stress

Toxic stress is the notion that multiple and long-term 'stressors' are hazardous to the human body. These stressors include things like fear of evictions and violence, environmental pollution, and economic insecurity. Prolonged levels of elevated stress are linked to negative health outcomes, especially in children (Evans & Schamberg 2009, Steptoe & Kivimaki 2012). Stressors can impact the body from in utero and throughout a lifetime when stress hormones, such as cortisol and adrenaline, are constantly released. This over-production of stress hormones results in greater inflammation inside the bodies, poor glucose regulation, arterial plaque, and damage to our brain's development. The toxic stress diagram in Figure 9 depicts a range of health impacts from environmental and social stressors present in Mukuru. The diagram emphasizes how factors contributing to stress that are largely outside of individual control can influence physical and mental health. For instance, the stress caused by factors such as poverty, poor sanitation, and gender inequity can lead to high blood pressure, cardiovascular disease, and poor mental health amongst other health outcomes. Moreover, it is not one singular stressor but rather the cumulative effects of multiple living conditions and inequities that result in persistent and toxic levels of stress in the body.

Figure 9 Toxic Stress and Health in Mukuru



ASSESSMENT

INDUSTRY
SOIL & FLOODING
SANITATION & NUTRITION

INDUSTRY & BUILT ENVIRONMENT

Mukuru is located adjacent to the Makadara industrial zone, which, at its nearest, is less than 3 kilometers from Nairobi's city center. ***There are over 1,000 industrial facilities surrounding the informal settlement, and these facilities act as major sources of pollution (Map 2).*** Industrial activities include a range of processes, from chemical manufacturing to auto repair and battery recycling. Hazardous pollutants are emitted directly from industrial facilities through smoke stacks and effluent pipes or are dumped into the Ngong River and in open areas throughout Mukuru, exposing nearby residents to disease causing agents and chemicals in the water, air, and soil.

Chemical industries are on the rise globally, with disproportionate growth in low and middle income countries (UNEP GCO 2018). Industrial waste products and pollutants can have significant adverse impacts on population health, and contribute to degradation of the natural environment. Though many regulation and environmental protection policies are enacted by the Kenyan National Environment Management Authority (NEMA), poor waste management and hazardous pollution remain a significant challenge for many cities in Kenya, where adverse impacts are felt most by the poorest urban residents. In cities like Nairobi, unregulated dump sites and concentrated sources of air pollution are often located within or adjacent to sprawling informal settlements.

Through interviews and field research, we found that residents regularly observe air pollution and surface pollution, such as oily, colored liquid, in drains and on roadways. At least one third of residents surveyed reported foul- smelling odors, eye and throat irritation, and coughing or other respiratory irritations at least once in the past month. Field reports noted that industrial waste was dumped and burned at dump sites within the community and directly discharged into the Ngong River.

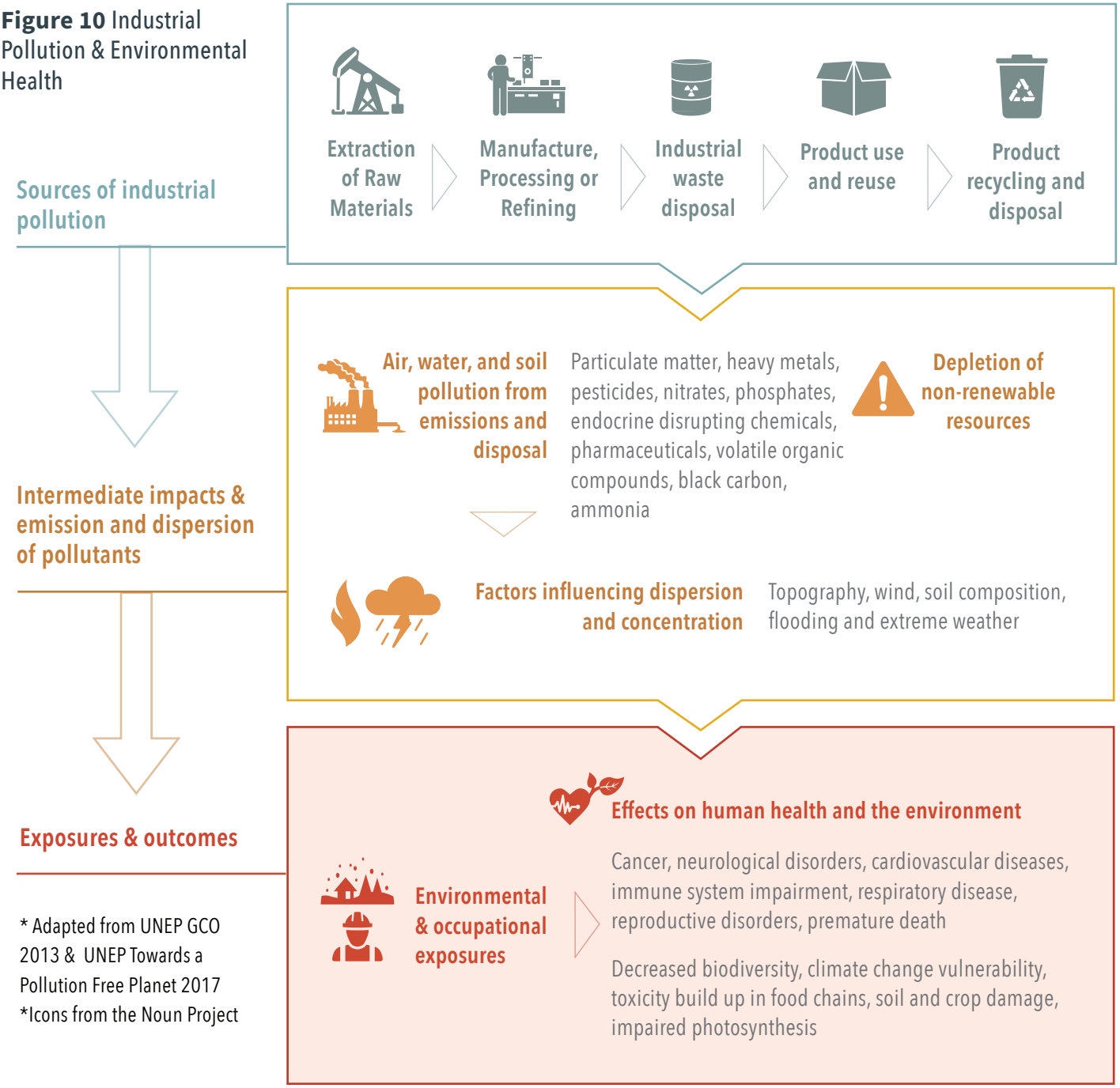
While residents of Mukuru are likely exposed to a wide range of industrial pollutants and chemicals, this report focuses on three key exposure risks based on the classification of nearby industrial processes:

1. **Heavy metals - particularly lead;**
2. **Volatile organic compounds (VOCs), and;**
3. **Particulate matter (PM).**

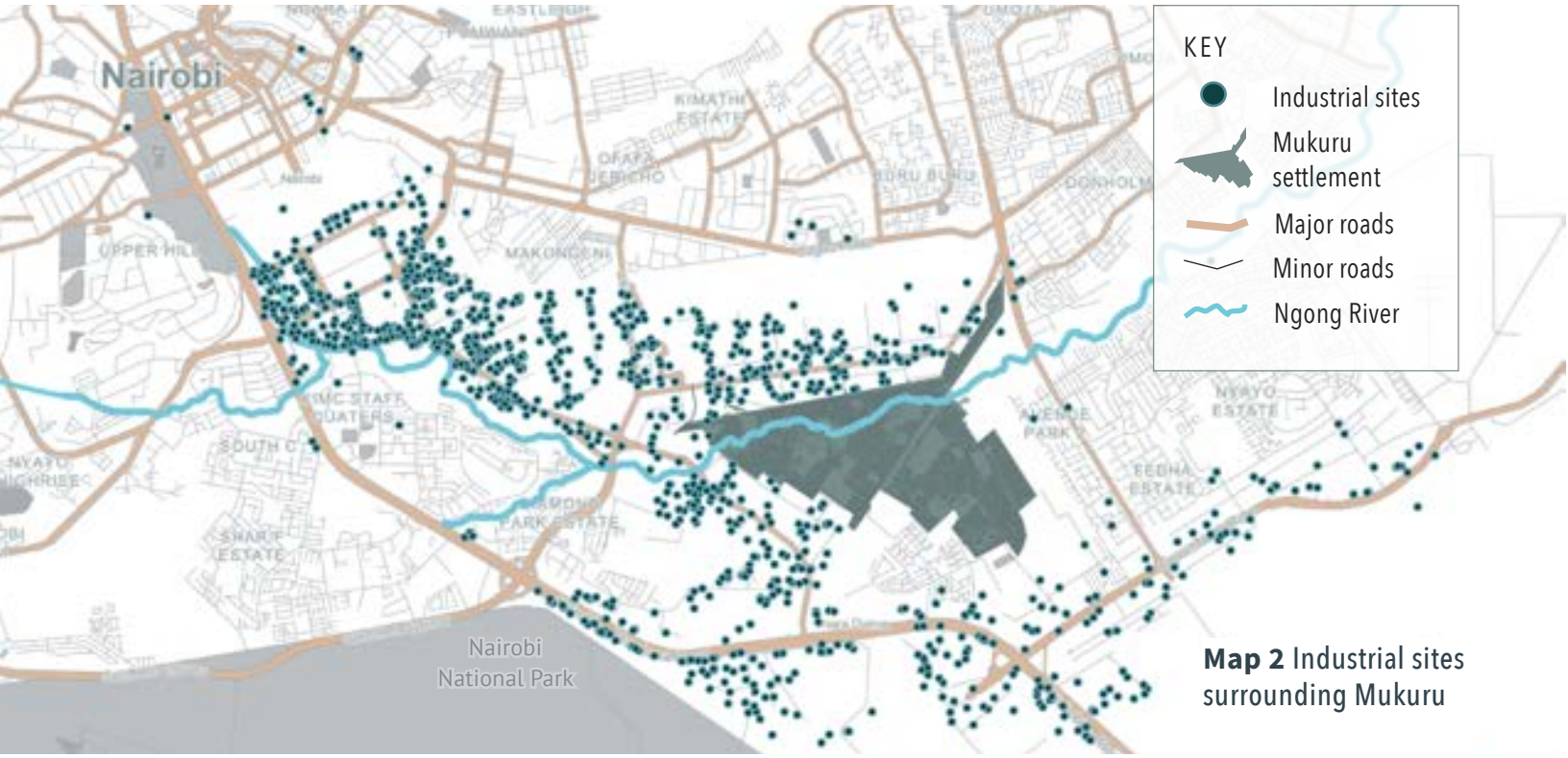
- Over 1,000 industrial facilities surrounding Mukuru
- Industrial pollution is worsened by poor roads, inadequate sanitation infrastructure, and flooding
- Hazardous pollutants include PM, VOCs, and Heavy Metals
- 19% of residents surveyed reported experiencing a cough in the past 6 months
- Children are particularly vulnerable to industrial pollution
- 43% of households surveyed that visited a health facility in the past six months reported cough as a top reason for seeking care

Figure 11 depicts a generalized pathway between sources of pollution and health & environmental outcomes. In this pathway, all steps in an industrial process from extraction of raw materials to the recycling and disposal of products and waste can result in air, water, and soil pollution. Once emitted, toxic pollutants interact with factors that influence dispersion and concentration, such as the topography of the environment or extreme weather events like flooding and fire. People and ecosystems are ultimately exposed to the industrial pollution, which contributes to poor health outcomes, premature death, and environmental impacts including climate change. In the following section, we discuss specific industrial processes and potential environmental and community health implications for the area surrounding Mukuru.

Figure 10 Industrial Pollution & Environmental Health



* Adapted from UNEP GCO 2013 & UNEP Towards a Pollution Free Planet 2017
*Icons from the Noun Project



Map 2 Industrial sites surrounding Mukuru

Industrial sites surrounding Mukuru are concentrated to the northwest of the settlement along the border of Viwandani and the Ngong River. In addition, clusters of more sparsely distributed industries are located south of the settlement. The concentration of industry adjacent to the Ngong River, which flows West to East through Mukuru, has created an active hazard for residents who are exposed to contaminated water and soil, particularly during the rainy season when the area is prone to severe flooding.

Characterizing Industry and Key Pollutants

This RHIA identified 1,151 industrial sites surrounding Mukuru. 718 of the sites have identifiable production processes, and are grouped into the following categories: 1. General auto, 2. Battery manufacturing, 3. Manufacturing of on-site chemicals and plastics, 4. Manufacturing of on-site metals, 5. General manufacturing, 6. General toxic services, and 7. Non-toxic services, (Figure 11). Given the high prevalence of auto, chemical and metal manufacturing sites, we find that residents of Mukuru are particularly at risk for exposure to heavy metals, volatile organic compounds (VOCs) and particulate matter (PM).

Six of the seven industrial categories identified were classified as toxic, the largest being general auto servicing and storage with 229 sites. Health risks and toxicity concerns in the general auto industry category include occupational exposures for workers as well as pollution and waste exposure for surrounding Mukuru residents. Exposure pathways include contact through servicing products such as brake cleaners, auto paints or solvents that contain multiple chemical hazards such as VOCs. Sources of toxic chemicals in the industry include paints; fillers and solvents; diisocyanates, polyisocyanates, and hexavalent chromium in spray paint; silica from sandblasting operations; dust from sanding; and metal fumes from welding and cutting. Surrounding residents can be exposed to these same chemicals through improper disposal techniques that contaminate surrounding air, water and soil.

General manufacturing includes any industries involved in the production of materials including but not limited to clothing and textiles, paper goods, pharmaceuticals and construction material. Given the broad nature of this category, many toxic pollutant exposure pathways are feasible. For example, clothing and textile manufacturing require high volumes of water, which at the end of production can be released as effluent containing dyes, bleach and chemicals such as acids and metallic salts. Additionally, the process of coating and drying textiles as well as storing the chemicals used in production can emit PM and VOCs into the air (Ghaly et al. 2014).

Following general manufacturing, the third largest group of industries has 106 sites categorized as manufacturers of on-site chemicals and plastics. This category is defined as the producers of a range of chemicals, plastics, and petroleum-based products including furniture, gas and packaging material. Major emissions from plastic and chemical manufacturing include trichloroethane, acetone, methylene chloride, methyl ethyl ketone, styrene, toluene, benzene, 1,1,1 trichloroethane, sulfur oxides, nitrous oxides, methanol, ethylene oxide and VOCs.

The fourth group of industries is categorized as the manufacturing of on-site metals. This category has 75 sites, and includes both the production and fabrication of metal products. The metal production process consists of casting, powder processing, and forming. Industries in metal product fabrication transform metal into intermediate or end products, or treat metals and metal formed products fabricated elsewhere. Fabricated metal processes include forging, stamping, bending, forming, and machining, used to shape individual pieces of metal; and other processes, such as welding and assembling, used to join separate parts together. Manufacturing of metals can contribute to air pollution through fumes and dust, water pollution from contaminated discharges or run-off, or soil contamination from accidental oil or chemical spills. Toxic pollutants from the manufacturing of on-site metals include PM, sulfur dioxide, ammonia and VOCs.

The fifth industrial category of general toxic services has 20 sites, and includes any industry or service provider deemed toxic on-site, such as printing, radiators, air conditioning, electronics and cigarette making, waste collection, and e-services.

The Mukuru area includes at least 5 automobile battery manufacturing sites. Common exposure routes for both workers and nearby residents include inhalation of inorganic lead dust in the air and exposure to lead leached into the soil from informal battery production, recycling, and dumping. Toxins of concern include various heavy metals such as lead, antimony, arsenic, cadmium, mercury, nickel, selenium, silver, and zinc and reactive chemicals, such as sulfuric acid, solvents, acids, caustic chemicals, and electrolytes.

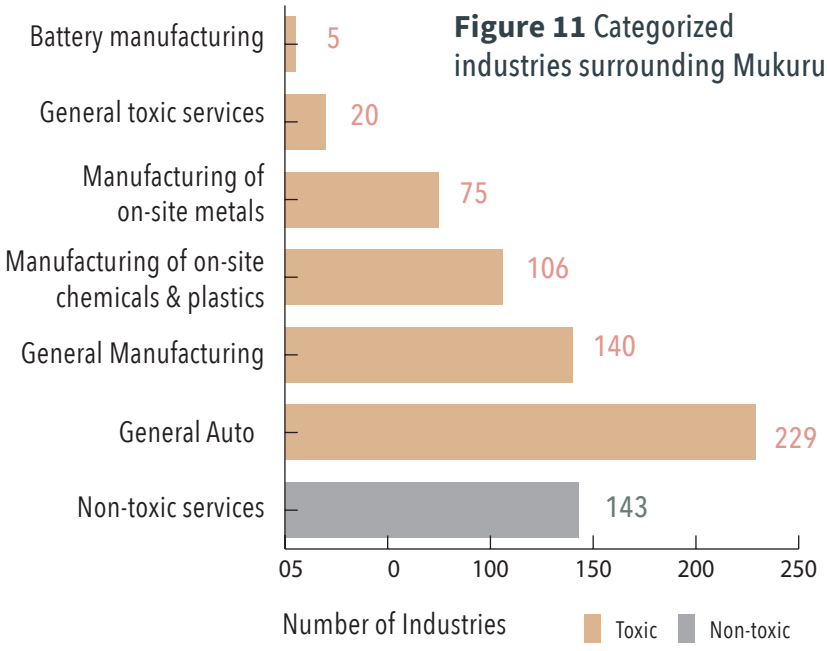
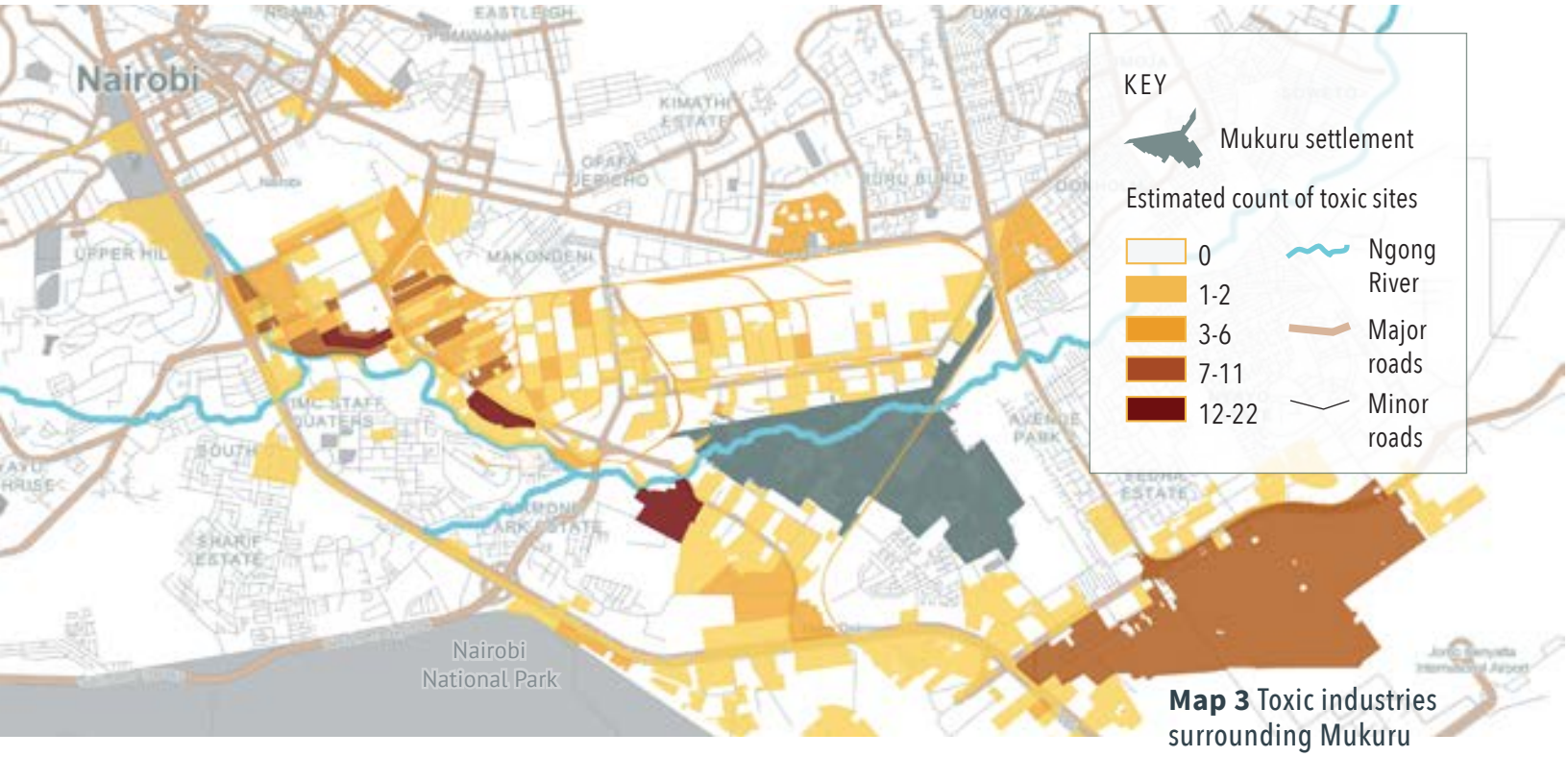


Figure 11 Categorized industries surrounding Mukuru



Map 3 Toxic industries surrounding Mukuru

Types of industrial pollution

Soil and water polluting industries are clustered in areas closest to the Ngong River, West of Mukuru. This is particularly concerning, given that the river flows from the West to East through the settlement. Contamination of the soil and water is worsened by frequent and severe flooding during rainy seasons, which impacts the river riparian zone and many of the neighborhoods throughout Mukuru.

Air polluting industries, depicted in Map 4, are also concentrated to the West of Mukuru. Residents in areas closest to the industrial zone in Viwandani and Kwa Reuben may be most severely impacted by industrial air pollution. Winds patterns in Nairobi show a concentration towards the North, Northeast, East, and Southeast directions, which likely exacerbates the health effects of heavy air polluting industries to the West of Mukuru.

Air Pollution & Community Health

Air quality has a critical impact on environmental and human health. In Mukuru, residents commonly report symptoms related to respiratory distress, such as cough and chest problems. In the 2018 SPA Household Health Survey, 19% of individuals reported experiencing cough in the past 6 months, and 43% of households that visited a health facility in the same period reported cough as a top reason for seeking care. An additional 12% of households that visited a health facility noted chest problems as a top reason for seeking care.

Particulate Matter Air Pollution

Particulate matter is a term for air pollutants consisting of liquid and solid particles such as dust, smoke and soot. PM varies in size, and the granularity of individual particles determines the severity of impact on health. PM 2.5 are fine particles that can cause severe damage as they reach deep into the lungs. PM 10 are coarser, larger particles that can cause eye irritation and

respiratory distress. Exposure to particulate matter has a range of health risks for the lungs and heart including irregular heartbeat; decreased lung function, aggravated asthma, and bronchitis; and premature death for those with lung or heart disease.

Heavy Metals

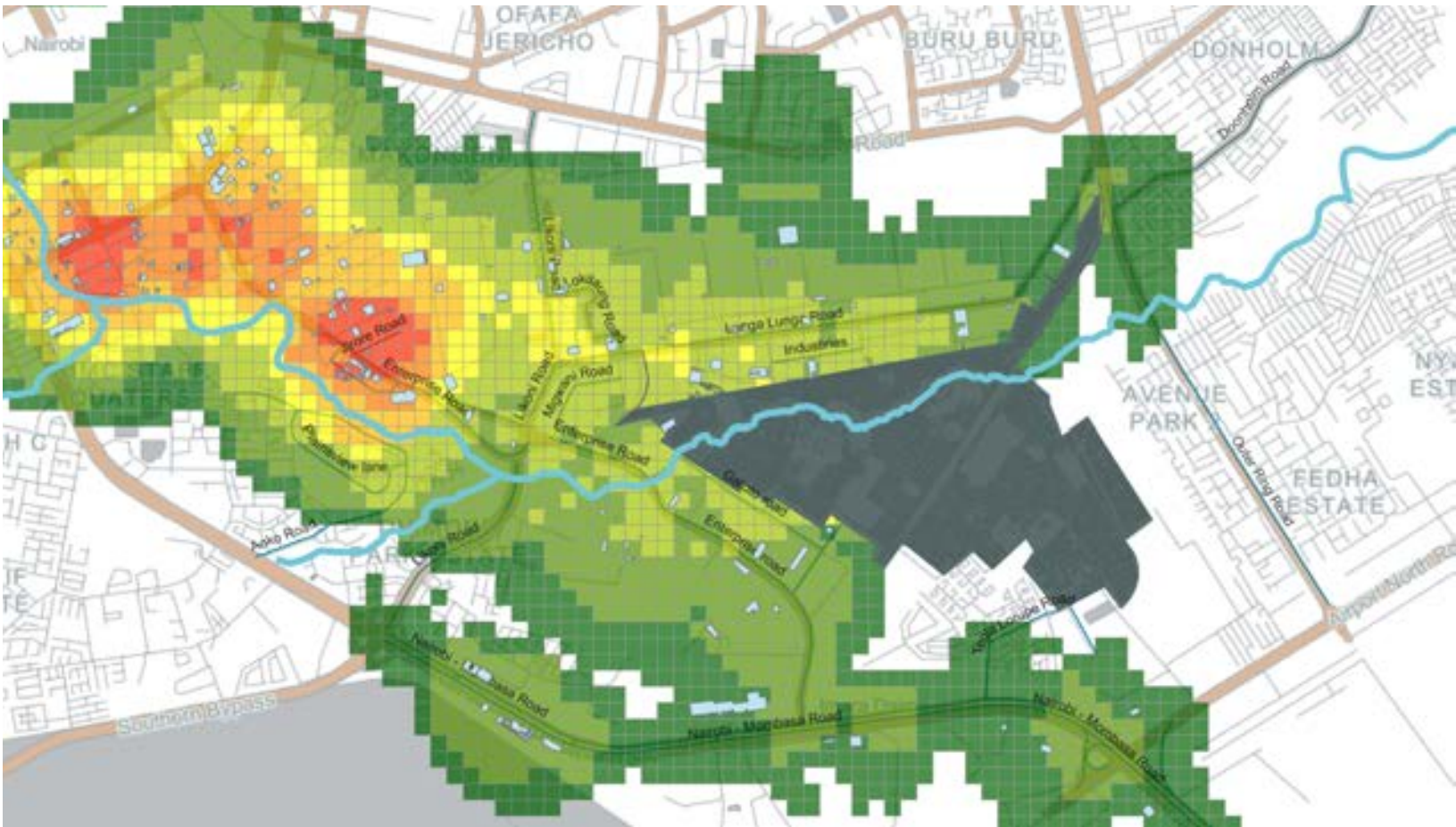
Of the 1,151 industrial sites identified in the area surrounding Mukuru, 309 were classified as heavy metal polluters. Exposure to heavy metals is associated with a range of both acute and chronic health outcomes such as kidney and bone damage, developmental and neuro-behavioral disorders, elevated blood pressure and lung cancer. Specific heavy metals of concern include lead, cadmium and chromium.

Lead (Pb) is an inorganic chemical that is neuro-toxic and can cause developmental issues. It accumulates in the bone and can be released into the bloodstream during pregnancy, becoming a source of exposure to the developing fetus. It can also cause high blood pressure, and if ingested, may cause organ damage through prolonged or repeated exposure. Lead exposure is highly dangerous for children, and has been linked to a drop in intellectual performance and other debilitating symptoms such as irritability and anxiety.

Cadmium (Cd), another heavy metal, is carcinogenic to the human body and is known to cause kidney and bone damage. Some of the likely impacts from this exposure include genetic defects, fertility issues or damage to a developing fetus.

Chromium (Cr) exposure can originate from either ingestion, inhalation or from skin contact. It can affect health in a number of ways including harming the respiratory tract and causing breathing issues such as asthma, coughing and wheezing; causing skin rashes; and harming the male reproductive system. Inhalation of chromium has also been linked to lung cancer.

Map 4 Air pollution near Mukuru



Volatile Organic Compounds

181 industrial sites surrounding Mukuru may be sources of toxic VOC pollution. VOCs pose significant health hazards to residents, with acute effects such as eye and respiratory tract irritation, headaches, dizziness, visual disorders and memory impairment, to more chronic conditions such as liver, kidney and central nervous system damage as well as various forms of cancer.

VOCs like Benzene, are carcinogenic (cancer causing) solvents. Through inhalation, Benzene can cause damage to the central nervous system as well as cause paralysis, tightening of the chest, convulsions and dizziness. Long-term exposure can decrease red blood cells and lead to anemia. It can also cause excessive bleeding and weaken the immune system, increasing susceptibility to infection.

Another common VOC is Formaldehyde, also a known carcinogen that has been linked to cancer of the throat and nose. Exposure to high levels of formaldehyde can cause build-up of fluid in the lungs, and lead to bronchitis, shortness of breath, and severe allergic reactions of the skin and eyes. This exposure can also cause menstrual disorders in women and girls.

Pollutant	Soil	Water	Air
Fine particulate matter (PM2.5, 10) containing sulphates, nitrates, ammonia, sodium chloride, polycyclic aromatic hydrocarbons, organic carbon, mineral dust, and water			X
Black carbon - a specific type of fine particulate produced from energy production and incomplete combustion			X
Nitrogen oxides emissions from transport, energy production			X
Sulfur dioxide			X
Ground level ozone			X
Volatile Organic Compounds (VOCs)			X
Heavy metals, including lead and mercury, from transport, energy production, industrial sources, contaminated sites, extractives industry, unregulated burning of waste	X	X	X
Pesticides	X	X	X
Plastic debris and litter	X	X	
Endocrine disrupting chemicals		X	

Figure 12 Figure 12. Key Industrial Pollutants

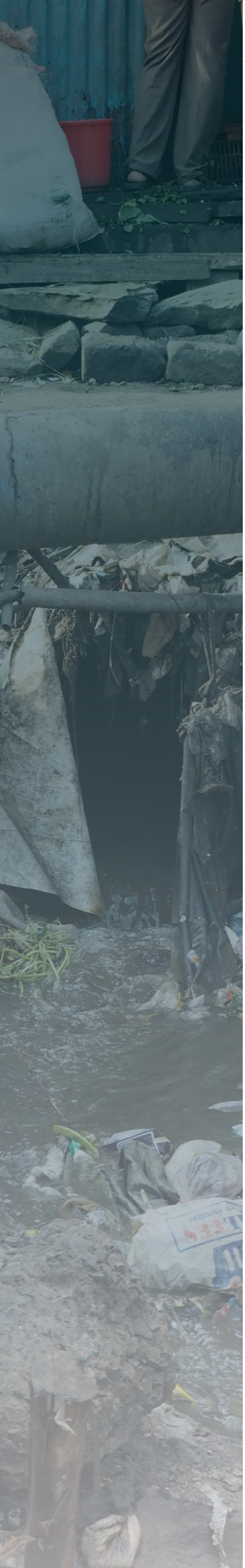
* Adapted from UNEP Towards a Pollution-Free Planet 2017

Figure 14 Lead Impact Analysis

Exposure Pathway	Health Outcome	Duration of Impact	Severity	Vulnerable populations
Inhalation or dermal contact with lead in the soil from the industrial dumping of batteries	Cognitive Impairment	Long-term	Extreme	Children
	Skin rashes	Short term	Moderate	Children
	Dizziness	Short term	Moderate	Children
	Headache	Short term	Moderate	Children
	Joint Pain	Long-term	Strong	Adults
	Reproductive problems	Long-term	Extreme	Women and children
	Anxiety and depression	Medium-term	Strong	Children
	Cardiovascular disease	Long-term	Extreme	Children
	Nausea	Short-term	Moderate	Children
	Asthma and respiratory illness	Long-term	Strong	Children
	Eye Irritation	Medium-term	Moderate	Children
	Allergies and hay fever	Long-term	Moderate	Children

Figure 13 Soil and water contamination pathway

**Icons from the Noun Project*



Case Study: ULAB Recycling: Humanizing the impact of industrial pollution on Mukuru residents

The University of Nairobi and University Eldoret conducted a study between January and August 2015 to investigate child lead exposure in the vicinities of used lead-battery (ULAB) recycling operations nearby the informal settlements of Mukuru, Dandora and Kariobangi. The study focused on two major lead exposure risks in each settlement: lead in floor dust and outdoor soil from dwelling units, residential areas, preparatory schools; and playgrounds nearby informal ULAB recycling operations. The study cites the following key findings:

- Lead contamination exceeded United States Environmental Protection Agency (US EPA) reference values in outdoor soils and interior floor dust in children's environments located within two kilometers radius from informal ULAB recycling operations in the Dandora, Kariobangi and Mukuru slums.
- Lead was detected in 100% of floor dust samples. Each floor dust lead loading measurement from dwelling units and preparatory schools in the Dandora, Kariobangi and Mukuru recorded lead loadings as high as 58,194 µg/ft2 , (about 6% lead) compared to the USEPA guidance value of 40 µg/ft2
- The recorded geometric mean soil lead concentrations were highest in the Mukuru slums, followed by Dandora, then Kariobangi. Waste dump and industrial soils in the Dandora, Kariobangi and Mukuru slums were found to have a high geometric mean lead concentration (2,630.5 mg/kg).
- Children living near informal ULAB activities in the Mukuru slums were predicted to have the highest geometric mean blood lead level followed by those living in Dandora, Kariobangi and Ruiru, consecutively.
- The costs associated with childhood exposure to lead can be quantified in the form of reduction in work performance and productivity as a result of IQ losses, increased health care costs and, behavioral and psychosocial problems, among others.

The researchers discovered that lead loadings in all the floor dust samples from the Kariobangi, Dandora and Mukuru slums exceeded the US EPA guidance value for lead on floors. Though there is no safe blood lead level, and even low blood lead levels ranging from 2 µg/dL to 10 µg/dL have shown to be associated to neurological damage for developing children, the study reports that nearly all (99.9%) of the children living in the Mukuru slums are likely to have blood lead levels above 34 µg/dL due to the exposure from floor dust and outdoor soil.

Predicted Blood Levels in Children 7 and Under

	Dandora	Kariobangi	Mukuru
Age (Years)			
0.5 - 1	27.3	25.5	44.1
1 - 2	25.1	23.3	40.5
2 - 3	22.7	21.1	37.1
3 - 4	22.3	20.7	36.8
4 - 5	22.1	20.4	36.7
5 - 6	21.4	19.7	36.0
6 - 7	20.3	18.7	34.4
% Exceedance of USEPA Guidance Value for Lead in Soil	95.7	94.0	99.7

Ondayo et al. 2016. Child Exposure to Lead in the Vicinities of Informal Used Lead-Acid Battery Recycling Operations in Nairobi Slums, Kenya." Journal of Health and Pollution

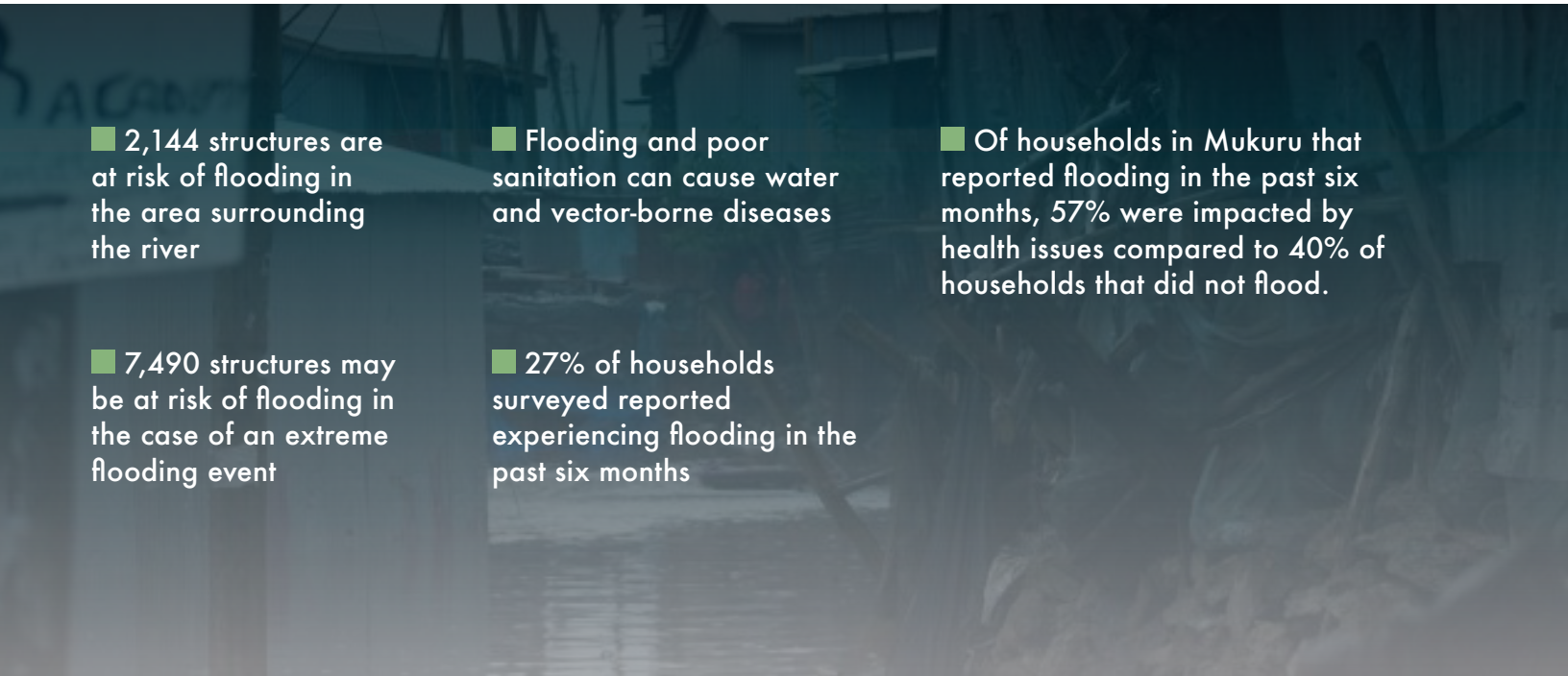
SOIL & FLOODING

The severity of flooding and associated health risks are particularly concerning in Mukuru. During the two rainy seasons from March - May and October - December, the area experiences a series of flood events that have already caused major building and infrastructure damage, displace people from their homes, caused children to miss school, and prevent employees from working. These flood events contribute to both health and economic risk for Mukuru residents and all residents of Nairobi.

Mukuru's proximity to the Ngong River combined with a series of unpaved roads, narrow footpaths, and poor waste management all contribute to the settlement's flood risks. Approximately one third (27%) of all households reported flooding in the past six months in the 2018 SPA Household Health Survey. This varied by settlement, with 34% of households reporting flooding in the past six months in Mukuru Kwa Reuben, compared to 21% in Viwandani.

Severe flooding, combined with industrial waste and poor sanitation infrastructure, expose residents to significant health risks including injuries, illness, and death. Standing floodwater damages structures and can cause them to collapse, while flash floods sometimes wash them away entirely, leaving people displaced or homeless. Flooding makes roads inaccessible, leaving communities stranded, and cutting them off from critical resources including health care and food. School closures due to flooding are also common, which disrupts local students' education.

In this section, we explore the major risk factors for flooding, simulate flood vulnerability scenarios, and estimate health and infrastructure impacts based on the topography and existing conditions in Mukuru. We focus on two major flood scenarios, one along the 30 meter river riparian zone, and another that explores flooding in low-lying areas in the event of extreme rainfall - what we call the "100 year flood".



2,144 structures are at risk of flooding in the area surrounding the river

Flooding and poor sanitation can cause water and vector-borne diseases

Of households in Mukuru that reported flooding in the past six months, 57% were impacted by health issues compared to 40% of households that did not flood.

7,490 structures may be at risk of flooding in the case of an extreme flooding event

27% of households surveyed reported experiencing flooding in the past six months

Factors contributing to Flooding in Mukuru

Mukuru is at a slightly lower elevation than the surrounding area of Nairobi, which contributes to increased flooding risks in the settlement. The average elevation in Mukuru is 1,623 meters, 39 meters lower than the average elevation in Nairobi, with some areas in the settlement as low as 1,600 meters.

The soil also contributes to the intensity of flooding. Mukuru is situated on black clay soil, which is mainly comprised of montmorillonite - soft phyllosilicate group of minerals with high swelling capability. The clay soil in Mukuru exacerbates flooding and also destabilizes structures. Black clay swells when it rains and shrinks in the dry months, causing floors to crack, walls and buildings to tilt, and potholes to form (Otando, 2005).

The Ngong River that runs through Mukuru carries pollution from surrounding industries into the settlement. Lead, Zinc, Mercury, and Iron have all been found in tests of the Ngong River water (Kithiia, 2007).

Development has altered the pathway of the Ngong River, which can also contribute to banks being destabilized and cause adjacent areas to flood. Dumping of solid waste in the river can impede water flow and act as a barrier for water to be absorbed into the soil, another factor that can prolong flooding.

Flood Risk Areas in Mukuru

The riparian zone (Map 7), a 30 meter buffer on each side of the river, is at increased risk of severe flooding and landslide, and homes here are frequently displaced during heavy rain. We estimate

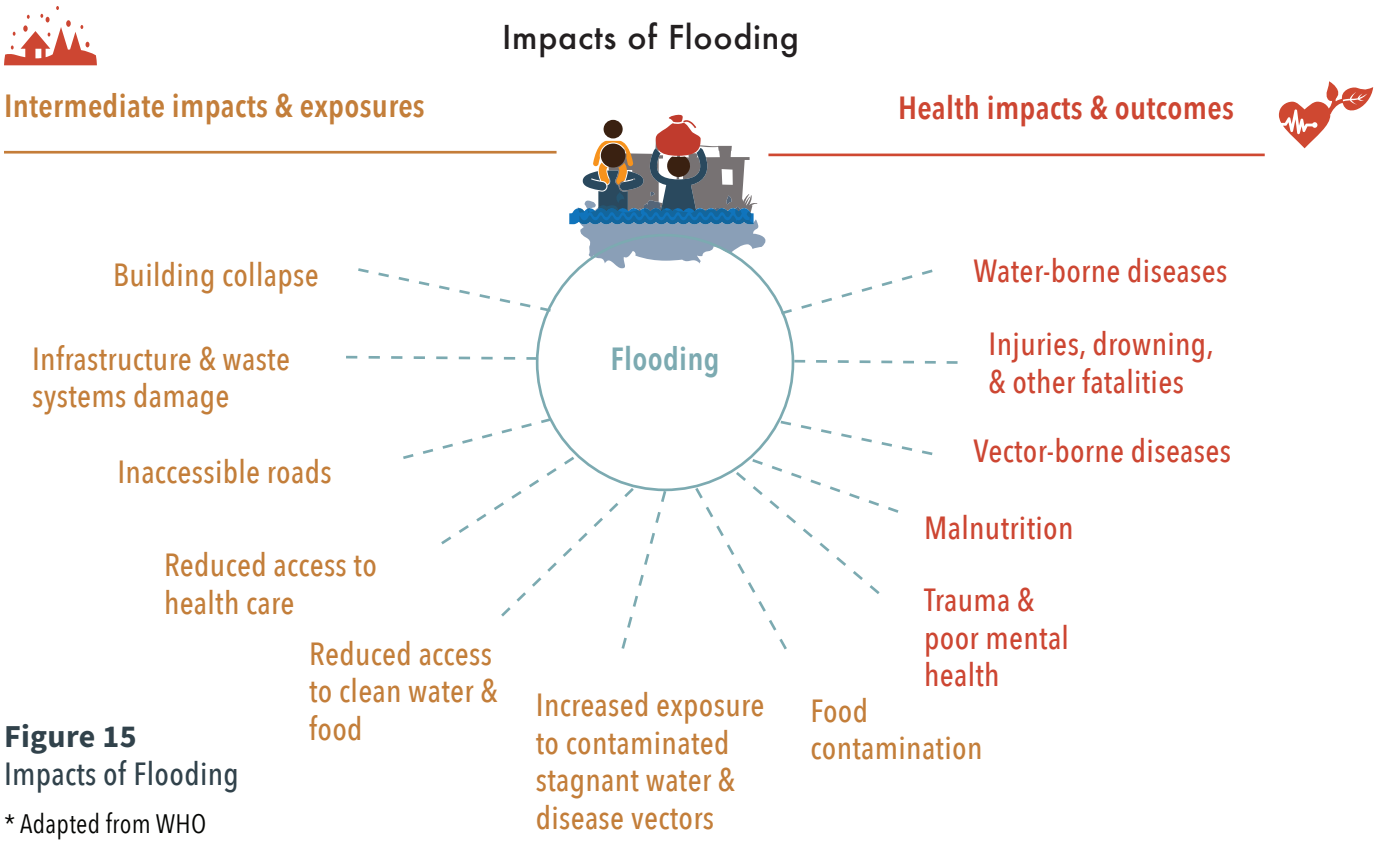
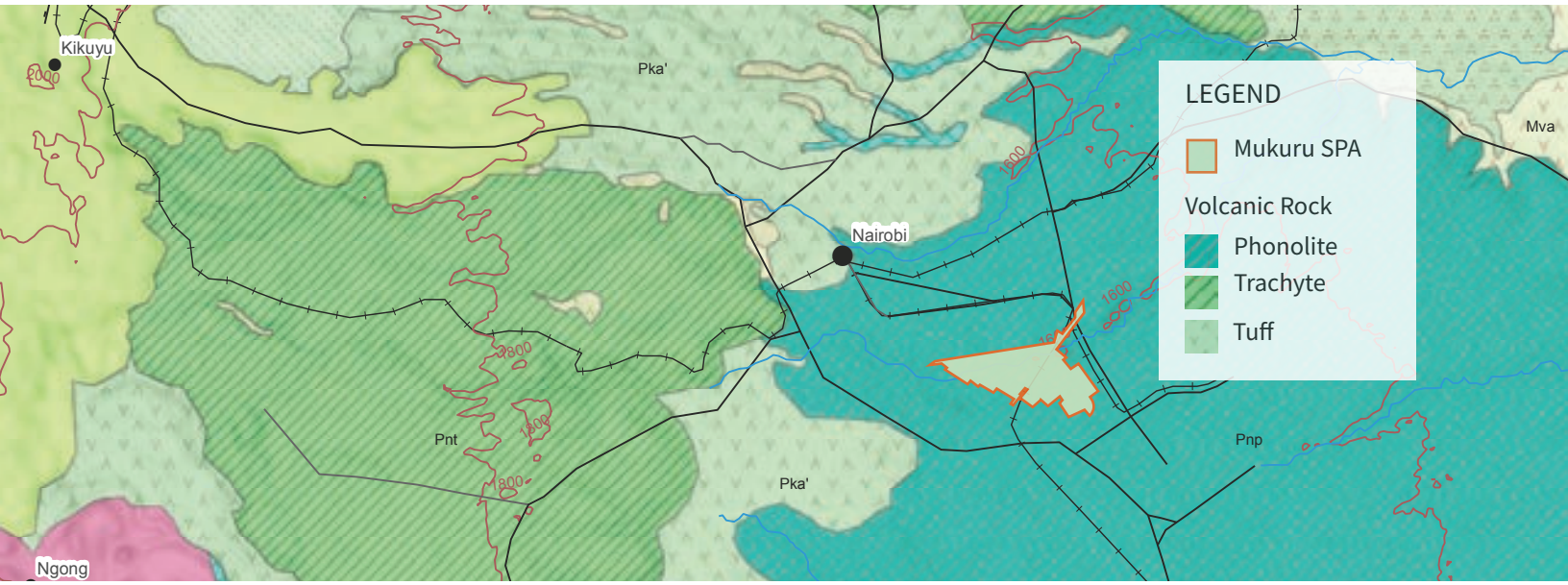


Figure 15
Impacts of Flooding

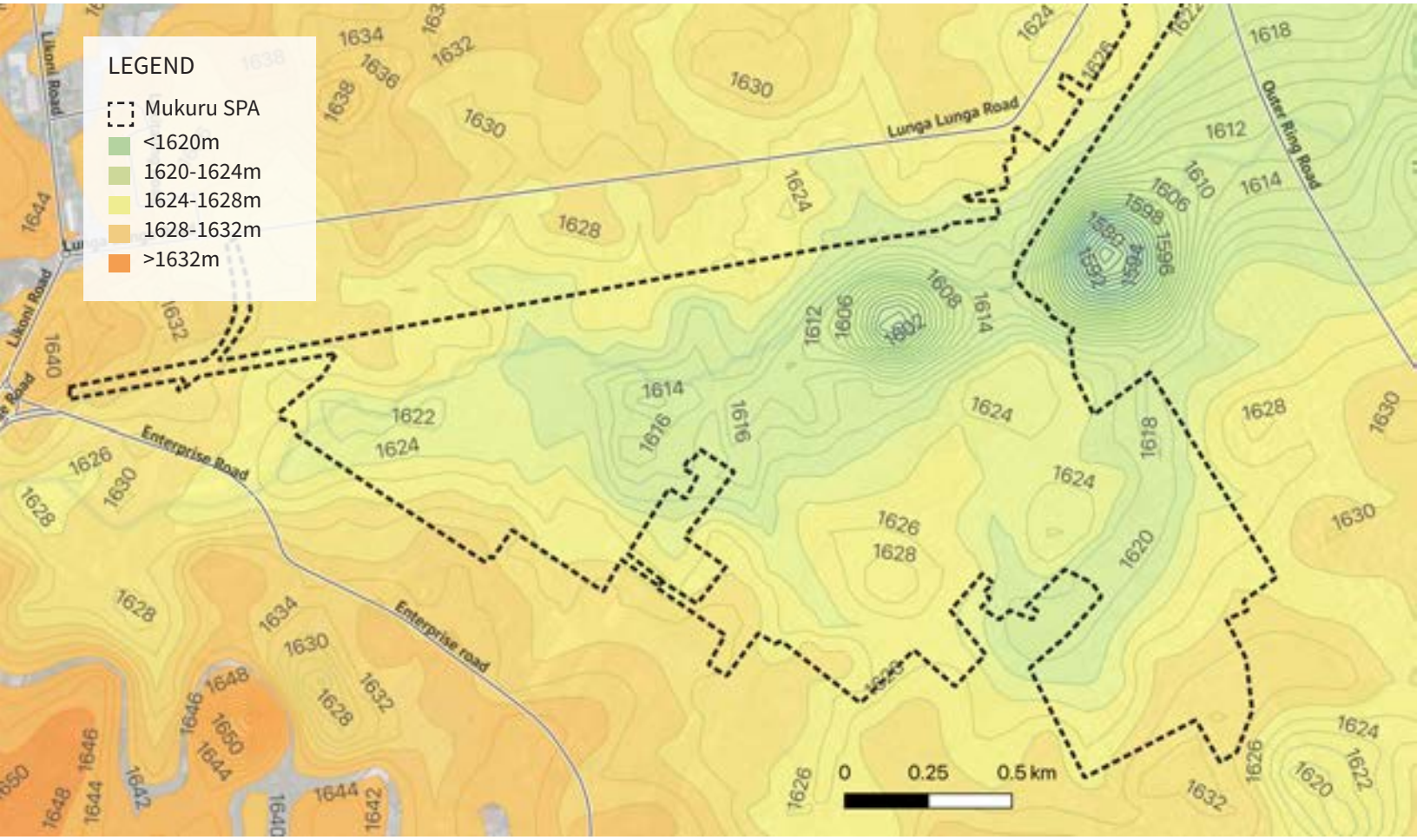
* Adapted from WHO

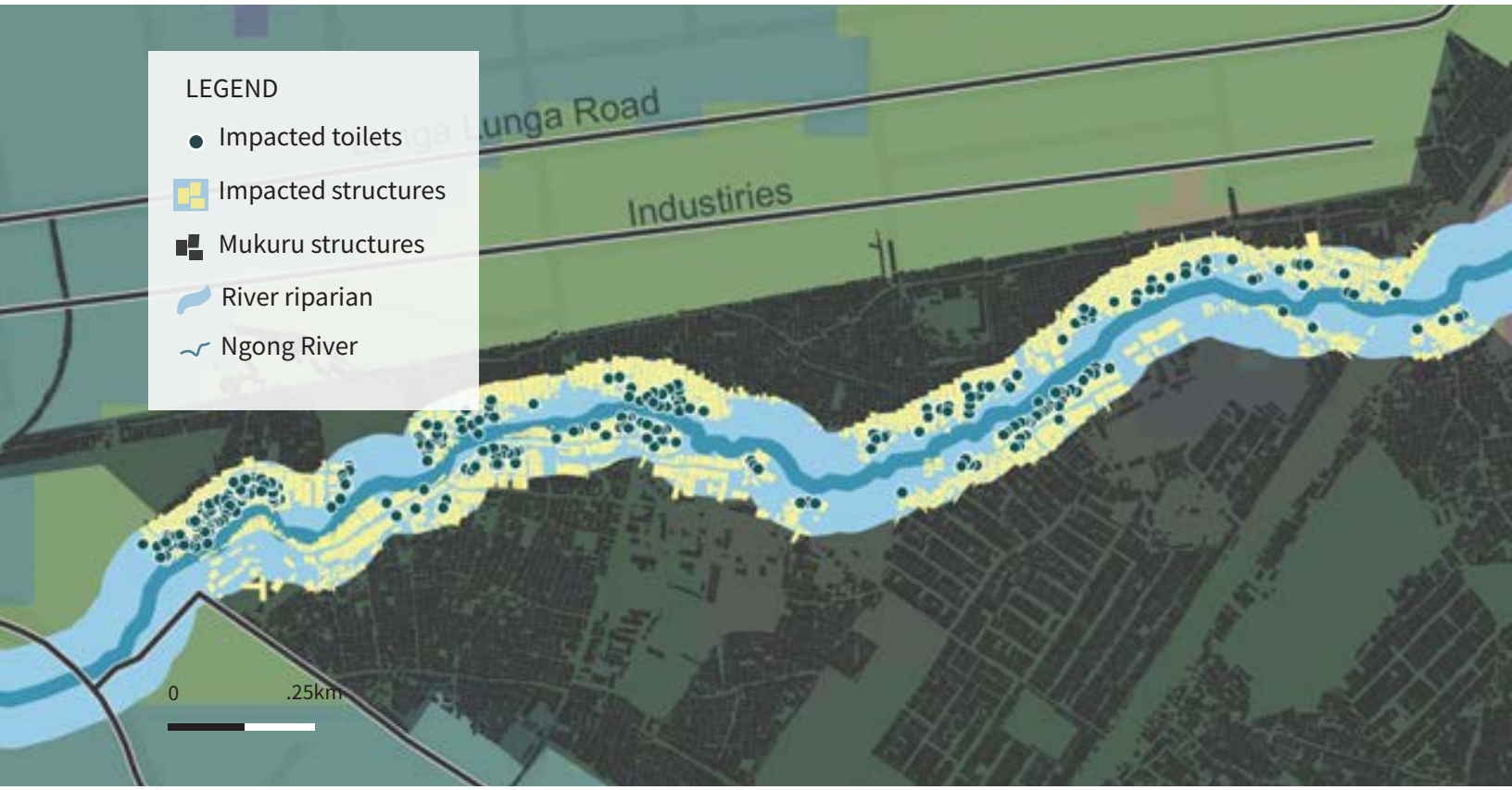
* Icons from the Noun Project

Map 6 Geology of Nairobi Source: Geological Society of America Chart and Map Series DMCH016



Map 5 Elevation of Mukuru and surrounding area





Map 7 Ngong River 30 meter flood zone and impacted structures

that 2,144 structures (each structure containing multiple households and/or businesses) may be impacted during a flooding event in this river riparian. 304 known toilet locations, both private, public, and yard-shared, reside within the 30 meter riparian zone. The flooding of toilet facilities, particularly pit latrines and those along the river, contribute to the spread of bacteria and hazardous waste during a flood event.

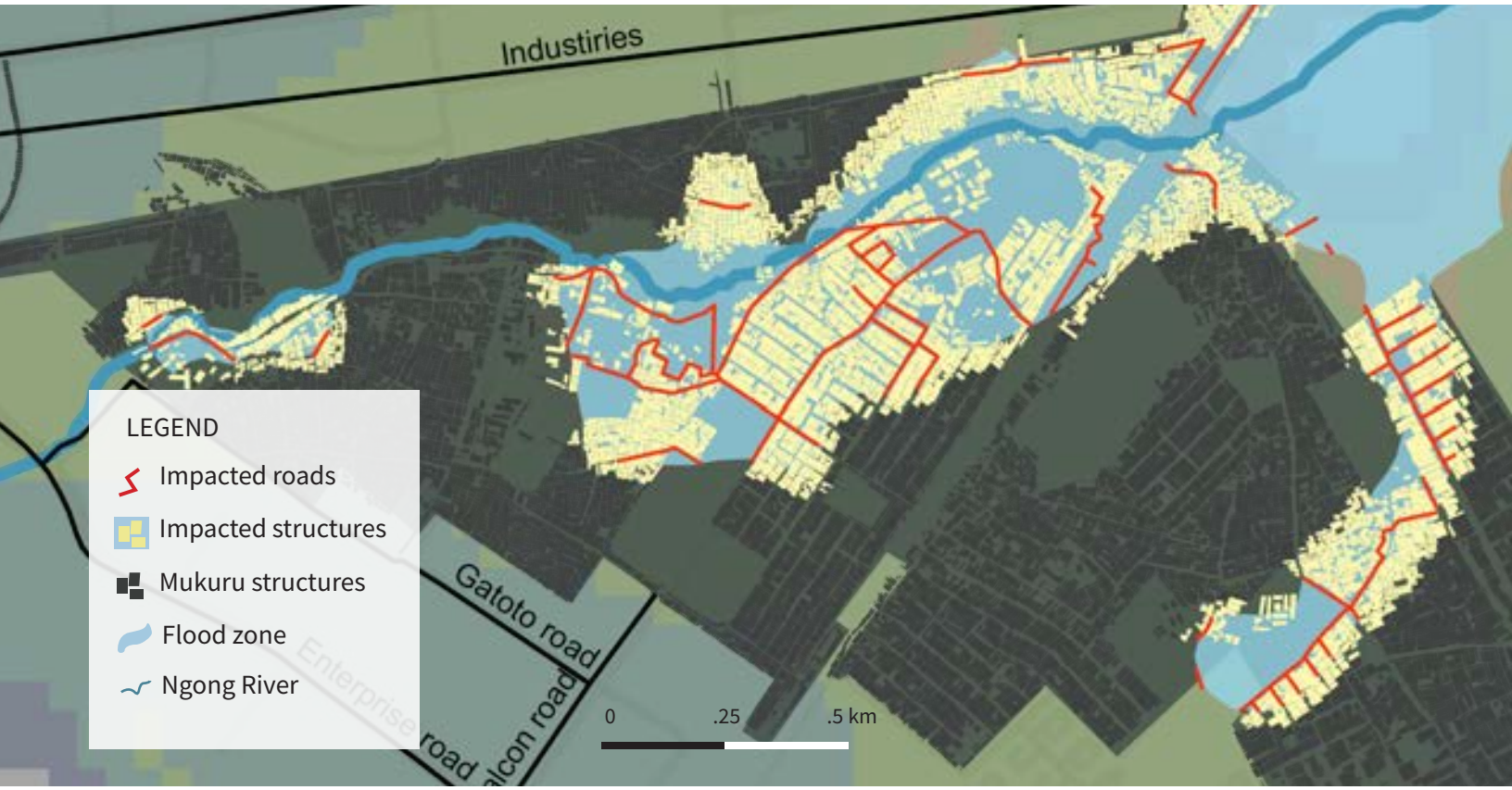
The communities of Mukuru Kwa Reuben, specifically the villages of Gatope, Mombasa, and Feed the Children, experienced a cholera outbreak during flooding in 2018. Additionally, The Hazina/ Kaiyaba bridge west of Mukuru Kwa Reuben and Viwandani in Mukuru Kaiyaba, is routinely submerged during and after heavy rainfall, and becomes impassable (The Citizen, 2015; CityLab, 2018) (Figure 17).

Using flooding histories and predicted "100 year flood estimates," we modeled the areas likely to experience major flooding in Mukuru (Maps 8&9). In this scenario, about 7,490 structures, major roads, and economic activities that impact all of Nairobi would be adversely impacted.

Health impacts of Flooding

Flooding in Mukuru can spread disease causing bacteria and toxic chemicals, contaminate food sources, and attract disease vectors such as mosquitoes when flood water becomes stagnant. Displaced and impacted residents can experience post-traumatic stress disorder, depression, and anxiety after flooding.

One major health concern related to poor sanitation and flooding is cholera, a deadly bacterial infection that spreads through contaminated water and food. In 2017, Tina's Education Centre in Mukuru Kwa Reuben was closed due to fears of cholera



Map 8 Mukuru: Modeled Major Flood Event "100 year flood"

Map 9 Mukuru: Major Flood Event impacted toilets

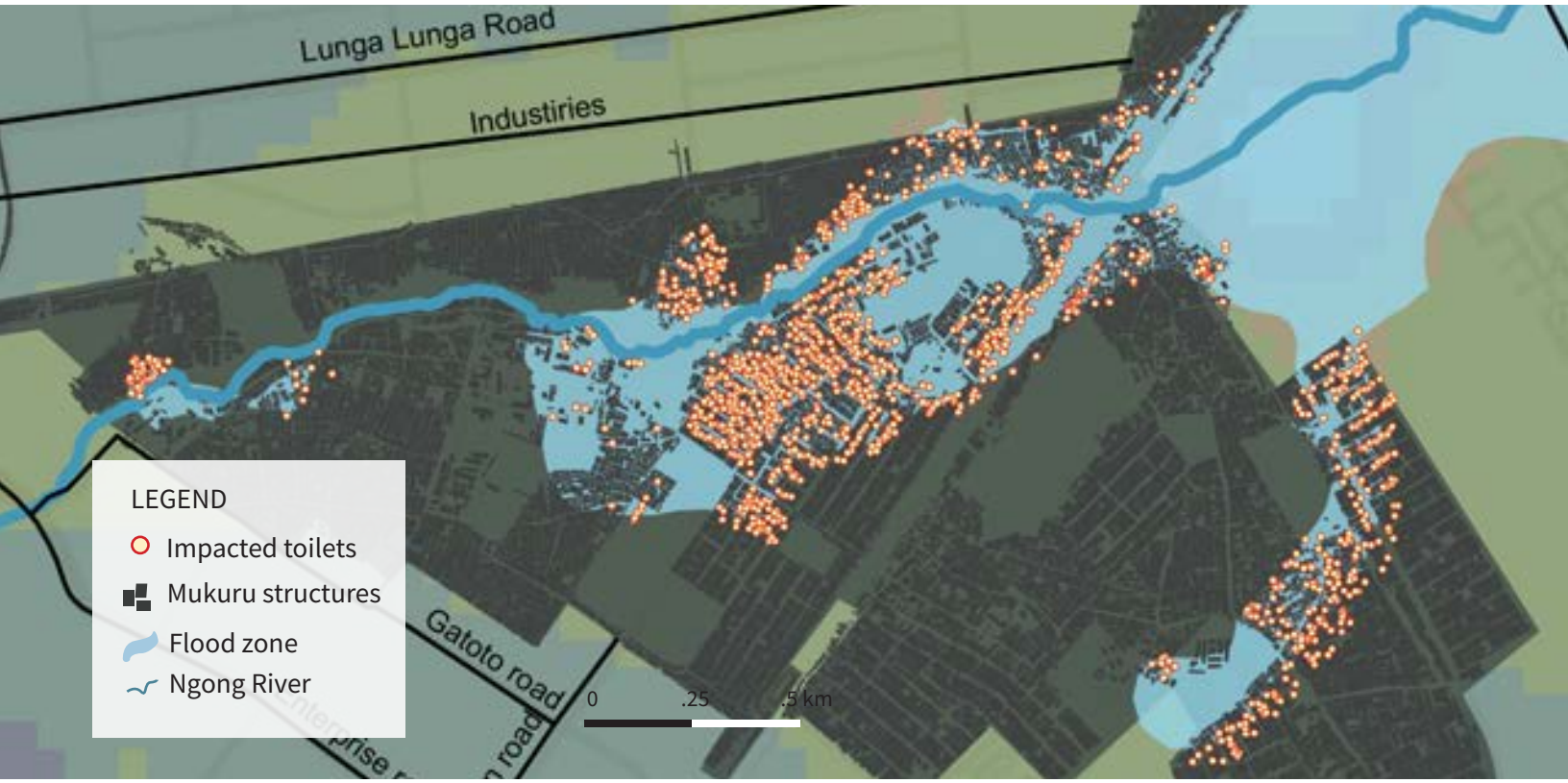


Figure 17 Flooding Impact Analysis

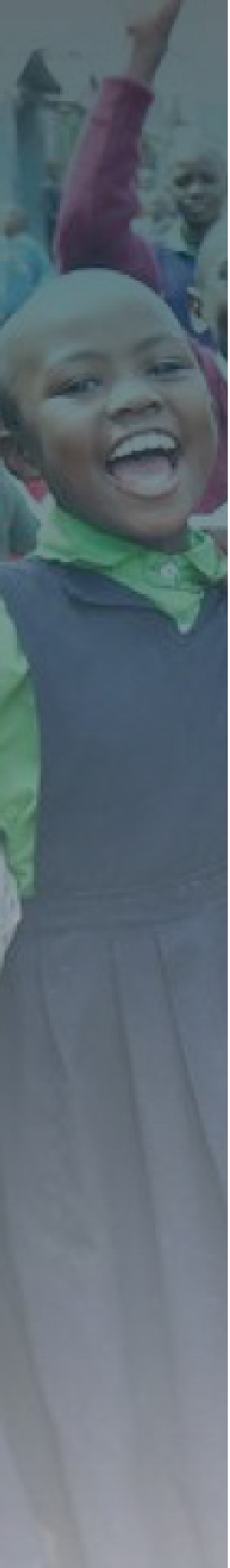
Impact	Duration of Impact	Severity	Vulnerable populations
Displacement	Long-term	Extreme	Children
Homelessness	Long-term	Moderate	Children
Property damage	Short term	Moderate	
Building collapse	Intermediate	Moderate	Children
Psychological trauma	Long-term	Strong	Adults
Trunk infrastructure damage	Long-term	Extreme	Women and children
School closures	Medium-term	Strong	Children
Inaccessible roads	Long-term	Extreme	
Diarrheal illnesses	Short-term	Moderate	Children
Neurological damage	Long-term	Strong	Children
Death	Immediate	Moderate	Children, elderly
Disrupted livelihoods	Long-term	Moderate	Women, small business owners

Figure 16 Hazina/Kaiyaba bridge flood *Source: Daily Nation*

outbreak (Daily Nation, 2017). Other health impacts associated with flooding include soil transmitted helminth (STH) infections, chronic diarrhea, typhoid & vector borne illnesses such as malaria, and debilitating mental health outcomes such as post. The pathway diagram in Figure 19 illustrates the cumulative negative health impacts of flooding and soil contamination on health in Mukuru. In this scenario William, a resident of the settlement, experiences poor health outcomes including rashes, diarrhea and gastrointestinal problems from bacteria and toxins in the soil and water. When the settlement floods, he must wade through the water, which at times can reach above his waist, and is exposed to hazardous runoff from waste and sewage that puts his health at risk. These negative health impacts can also result in cyclic poverty for William and his family due to high costs of treatment, losses in wages from missed work, and costs to repair property damage or having to rebuild or relocate their home altogether after a flood.

Figure 18 Pathway diagram: health impacts of flooding

* Icons from the Noun Project



Case Study: Impacts of Flooding on Embakasi Girls Secondary School

The impacts of flooding in Mukuru are well illustrated by Embakasi Girls Secondary School's story. Whenever it rains heavily, the campus floods, disrupting the learning of 500 students from Mukuru and the surrounding area. Water fills the classrooms, dormitories, offices, and storage areas, and has damaged books and computers. In March 2018, the flooding was so extreme that students were displaced from their beds and had to sleep in classrooms. In some rooms, the floodwaters reached 50 cm. The girls were forced to wade through water to move between buildings and the school was closed for 2 days. Wastewater from the sewer also runs onto the school compound when it rains, bringing a putrid smell that distracts students from their studies.

The school began flooding in 2012 when the expansion of Mukuru kwa Reuben and Mukuru kwa Njenga began blocking existing drainage routes. The head teacher, Mrs. Geke has described her understanding of the growing flooding problems, saying:

"There used to be a wide drainage when the school was established in 1998 but due to the encroachment on top of the drainage, all the water now backtracks to the school whenever it rains because the school is at the lowest point" (Kimuyu, 2018).

The school's walls were poorly constructed and allow water to enter the buildings easily. The current dormitory was meant to be a temporary structure after the previous building burnt down in 2015, but the project stalled due to lack of payments.

The displacement, disruption, and property damage Embakasi Girls Secondary School has faced due to flooding are all too common in Mukuru. Many students miss school after heavy rains, and adults are often unable to work too. The land use and drainage challenges that Mrs. Geke raises are persistent throughout Mukuru – a byproduct of the limited space, growing demand, and unfettered urbanization. This case study highlights the urgency around addressing these issues and taking action to prevent flooding in Mukuru.

KTN News Kenya. (2014, October 18). NAIROBI RAINS: Embakasi Girls Secondary School is closed after heavy rains cause havoc in Nairobi

Source: TUKO Kenya, 2018

SANITATION & NUTRITION

Inadequate sanitation is linked to poor nutrition and related health impacts. In Mukuru, exposed sewage and human waste in surface drains and high costs for clean water combine with frequent flooding and unhygienic food preparation & handling to contaminate food and contribute to nutrition-related illnesses. Measured conditions in Mukuru include parasites, diarrhea, chronic stress, low height for age (stunting), low weight for height (wasting), and poor maternal health outcomes. Poor nutrition can contribute to decreased school performance, reduced work productivity and gender inequities.

Figure 20 provides an overview of health impacts associated with poor sanitation & nutrition, stemming from a lack of infrastructure, high costs, and environmental contamination.

Poverty Penalty on Sanitation

Residents tend to pay more for similar services in Mukuru than in other parts of Nairobi, resulting in an economic penalty that contributes to cyclic poverty and poor health (Taffa and Chepngeno, 2005). Food and WASH represent major expenditures for households in Mukuru, where costs can consume a significant percentage of monthly household income. According to the Kenya Integrated Household Budget Survey of 2017, households in Mukuru may spend up to 70% of their income on food and sanitation, and poorer households in the lower income quintile spend more than they earn for both needs in a four-week recall period. Residents are vulnerable to price increases and other market shocks.

Quality and Accessibility of WASH

Poor sanitation and the lack of sewage systems in Mukuru have critical economic and health costs for residents in the settlement. Map 9 highlights the 1,356 toilets, many of which are pit latrines, that may be inundated during an extreme flooding event. In this scenario, flood water combined with sewage and polluted river water may enter homes and businesses, contaminating food and water sources and displacing residents.

Options for sanitation facilities are often informal in nature, and most households use communal or public pay-per-use facilities that are typically less safe and more likely to spread bacteria. Less than one percent of households in Mukuru have access

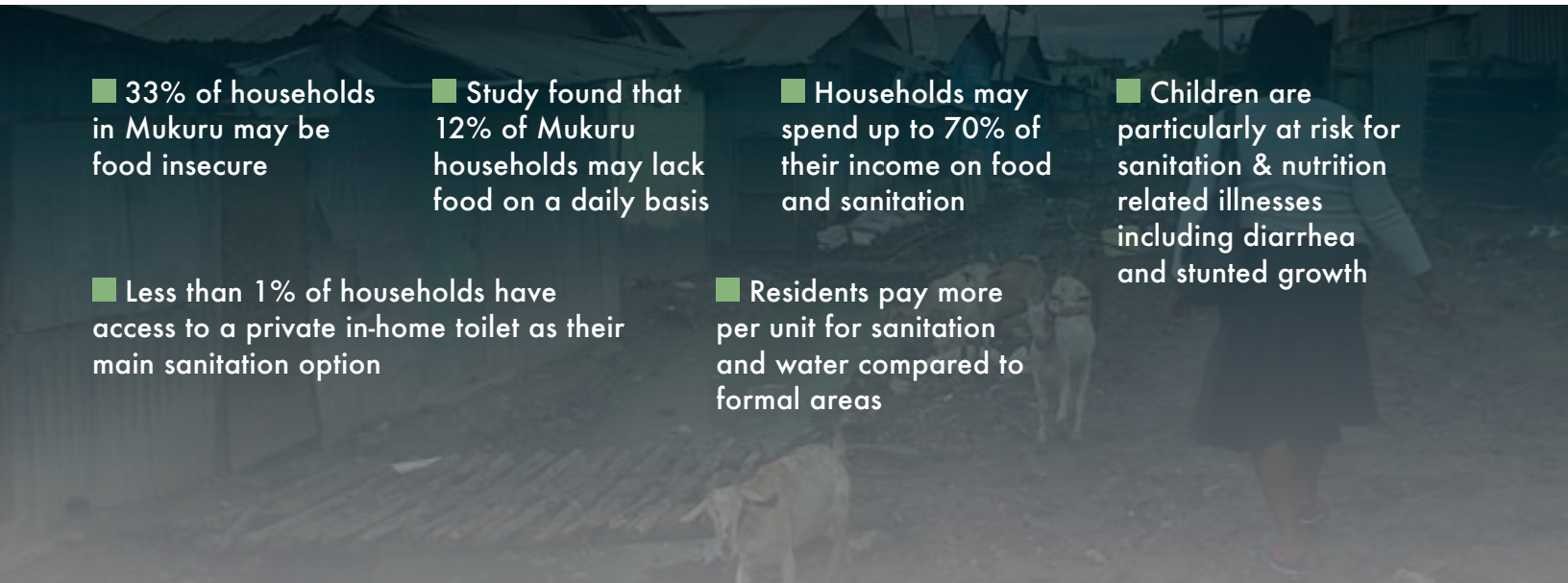
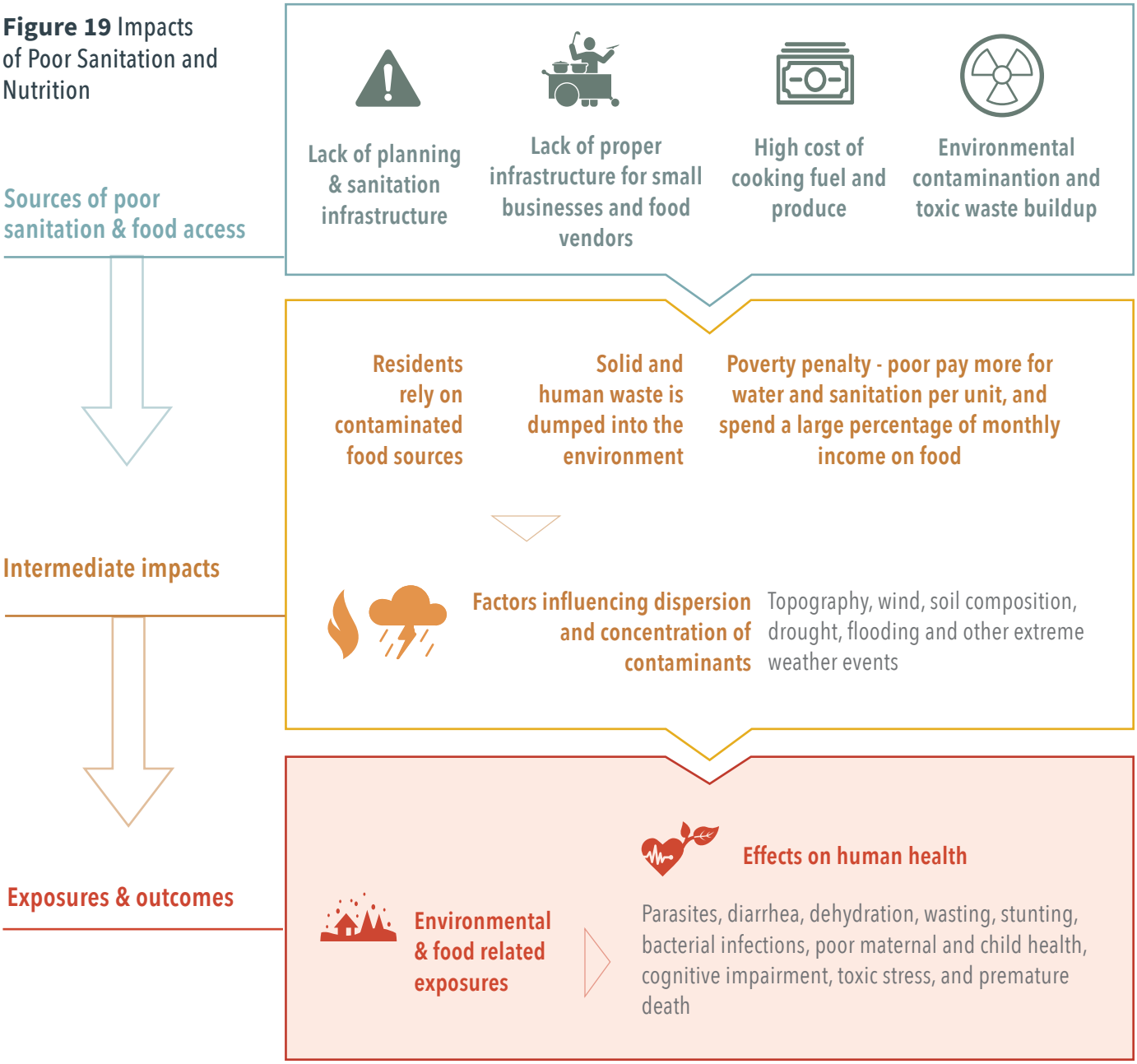


Figure 20 Food vendor cooks along a street in Mukuru

Figure 19 Impacts of Poor Sanitation and Nutrition



to a private in-home toilet, and the remaining residents use yard-shared toilets (shared with 10-12 neighboring households) or public toilets (typically at a rate of 5 KES per use). The majority of toilet facilities in Mukuru are not connected to a sewer line, and rely instead on pits that must be emptied manually or that flow into open street drainage adjacent to structures and roads.

Toilets access is not only limited by affordability, but by safety and proximity to homes, especially for women and children who may be at greater risk for assault when using public facilities. Many public facilities are closed at night, which contributes to the use of flying toilets and open defecation.

In Mukuru, 82% of available sanitation facilities are yard-shared, typically amongst at least 150 people. Only about half (52%) of residents of Mukuru lived within 50 meters of a toilet facility, and only 54% had access to a bathing facility (Mberu, Haregu, Kyobutungi, & Ezeh, 2016).

Quality and Accessibility of Nutrition

Over 1/3 of households in Viwandani Settlement are severely food insecure and 24% of households reported skipping meals or eating less due to lack of resources after an illness.

Households in Mukuru purchase food from informal food markets, formal markets, street vendors, and grocery stores within and outside of the settlement. Streets in Mukuru form popular food corridors featuring open-air food kiosks and cooking sheds. According to a report published by the Hungry Cities Partnership, up to 46% of micro-enterprises are involved in food retail business, and 38% of them sell cooked food. Eight in ten street food vendors are located within five meters of a road lacking any formal drainage, exacerbating the likelihood of food contamination.

While street food vendors may provide affordable options to Mukuru residents, challenges with dietary diversification, nutritional content, and food contamination may offset benefits. Poorer and larger households may cope with food insecurity by consuming foods with greater energy density and less micro-nutrients to make up for fewer or missed meals.

In the 2016 Strathmore University household finance survey, over 12% of respondents in Mukuru stated they lacked food on most days, and the same percentage also lacked water on most days. 36% of respondents reported purchasing food from the neighborhood kiosk, and 73% stated that they purchase foodstuff for home consumption on a daily basis rather than weekly. Daily food expenditure was 200Ksh for 19% of respondents and 300Ksh for 16% of the respondents; 6,000ksh and 9,000kshs monthly expenditure respectively. Thus, food

Figure 21 Figure 22. Example of food vendor in Mukuru Kwa Njenga

expenses equal between 40-70% of total monthly income for Mukuru residents. Yet, the Hungry Cities report found that food expenditures were about 52% of total household income for households living in Nairobi informal settlements, and only 16% for residents in formal areas of Nairobi.

Exposure Pathways and Health Impacts

Figure 24 provides a detailed pathway diagram that links sanitation and nutrition for informal settlement residents.

Undernutrition

Undernutrition is characterized by low weight for age (underweight), low weight for height (wasting), and low height for age (stunting), and results from insufficient intake or absorption of necessary nutrients. While undernutrition is more commonly associated with starving, it can also be caused by parasites and digestive tract infections with severe and repeated bouts of diarrhea that prevent the body from properly absorbing nutrients. Population health studies indicate a high prevalence of diarrhea in Mukuru, with over 40% prevalence in children (APHRC Report, 2013). Another study conducted in Mukuru found that 40.6% of 160 participating children had stunted growth. The same study quantifies the prevalence of wasting in Mukuru at 13.3% and 30.5% for underweight children (Muoki, 2008).

Though reported cases of diarrhea were low in the 2018 SPA Household Health Survey, at 5% for all individuals, the survey found that diarrhea was twice as common (10%) in children between 0-4 years old, and that the percentage of individuals who reported experiencing diarrhea dropped to 2% for those who had water connections in their home and those who use a closed pour flush toilet as their main sanitation option A higher percentage of those who use pit latrines and who had extended time to nearest water source (more than 30 minutes) reported experiencing diarrhea compared to all respondents

Parasites

Parasites, which can contribute to undernutrition, include a range of intestinal worm infections and can be transmitted through contaminated food, water, and soil. A 2013 study conducted in Mukuru found that 25% of children under 5 who presented with diarrhea tested positive for at least one parasite, and that patients with HIV were more likely to be infected than those without the disease (Mbae et al. 2013).

Cholera

Cholera is associated with fecal-oral contamination, caused by the bacterium V. Cholerae. In 2009, a cholera outbreak hit Kenya, with 43 fatalities in Mukuru - the highest in the country (Blanton et al. 2015). In 2015, 40 cases of cholera were reported in Mukuru Kwa Ruben (ACF, 2010).

Figure 22 Cumulative health risks along street in Mukuru

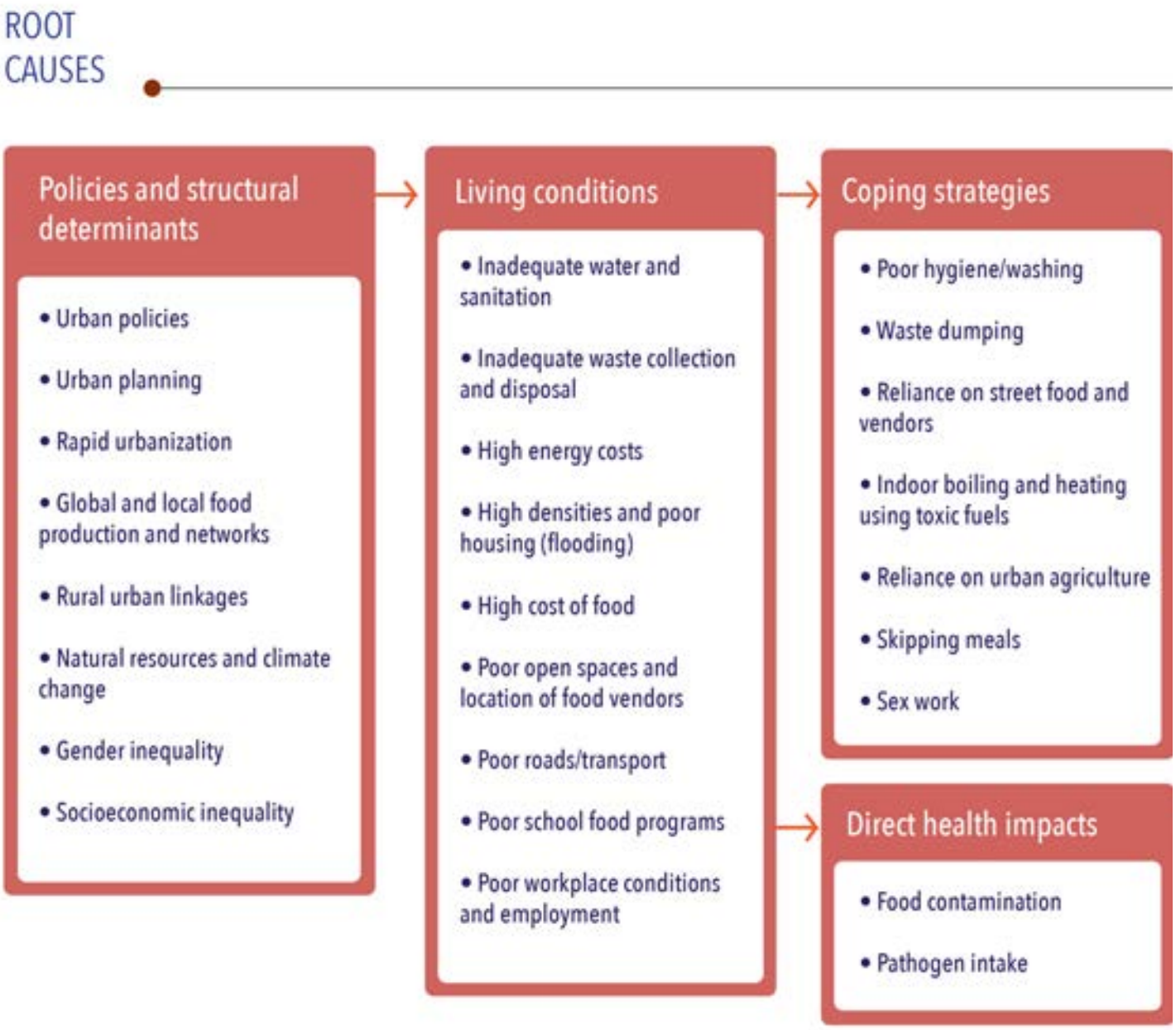
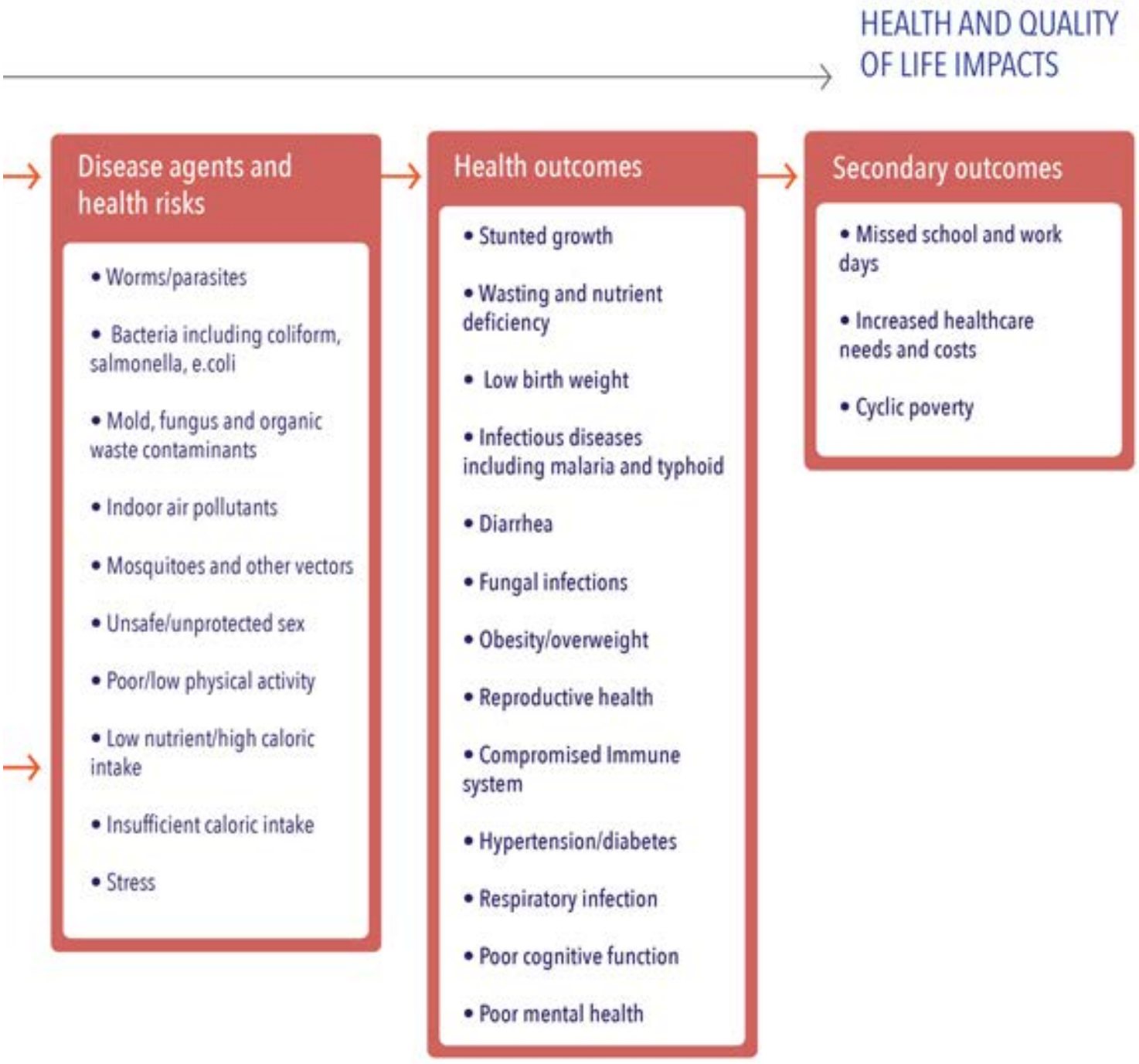


Figure 23 Figure 24. Sanitation and Nutrition Pathway Diagram


HEALTH AND QUALITY OF LIFE IMPACTS
Disease agents and health risks
• Worms/parasites
• Bacteria including coliform, salmonella, e.coli
• Mold, fungus and organic waste contaminants
• Indoor air pollutants
• Mosquitoes and other vectors
• Unsafe/unprotected sex
• Poor/low physical activity
• Low nutrient/high caloric intake
• Insufficient caloric intake
• Stress
Health outcomes
• Stunted growth
• Wasting and nutrient deficiency
• Low birth weight
• Infectious diseases including malaria and typhoid
• Diarrhea
• Fungal infections
• Obesity/overweight
• Reproductive health
• Compromised Immune system
• Hypertension/diabetes
• Respiratory infection
• Poor cognitive function
• Poor mental health
Secondary outcomes
• Missed school and work days
• Increased healthcare needs and costs
• Cyclic poverty

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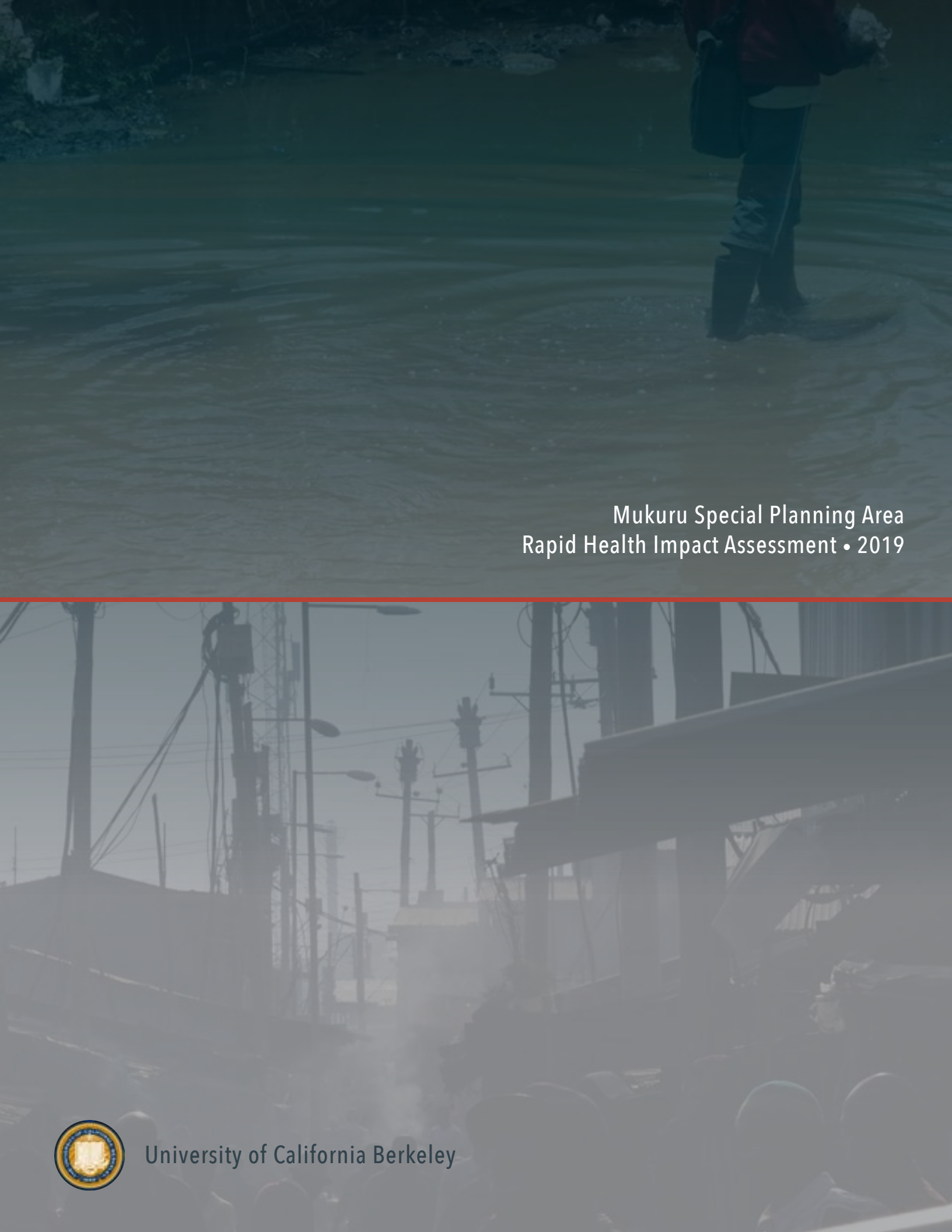

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