Assessing the effects of household water, sanitation, and hygiene (WASH) on child health under different socioeconomic and community contexts: A mixed-methods study in northwest Ecuador

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Abstract

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Water, sanitation, and hygiene (WASH) access is both a direct determinant of health and an indirect determinant of numerous other conditions important to well-being. The WASH-related health burden – primarily enteric infections and poor child growth – falls disproportionately on the poorest households. This dissertation seeks to understand how WASH access, household wealth, and child health intersect at the numerous scales at which WASH operates, from the individual to the household, community, and broader geographic and environmental contexts. We ground our work in an understanding of the sociopolitical and historical processes which have shaped inequitable access to WASH and health today, and center the voices and experiences of community members and mothers as crucial context for our research.

In Chapter 2, we utilize mixed-methods and a socioecological framework to understand maternal preferences and priorities related to WASH access in ten communities spanning an urban to rural gradient in northwest Ecuador. We conducted 33 in-depth interviews with mothers participating in the ECoMiD study, and identified drivers and constraints to WASH access at the individual (time and labor), household (WASH access and costs), community (infrastructure

quality), geographic (natural resources, remoteness), and environmental (seasonal impacts) levels. Mothers were hesitant to invest in WASH in the absence of secure, permanent housing.

In Chapter 3, we assess the relationship between household wealth and household WASH in the ECoMiD communities across the urban to rural gradient. To complete this analysis, we used qualitative data from Chapter 2 to create a community-informed measure of socioeconomic status, constructed using multiple correspondence analysis on asset ownership. We found that wealth was significantly associated with increased access to complete WASH, a metric that includes access to basic or limited water, basic or limited sanitation, and basic hygiene in a household. Among these components, wealth was most strongly associated with increased sanitation access. High wealth thresholds were identified to own priority WASH items.

In Chapter 4, we test if household WASH and household wealth have a protective effect against enteric infection and stunting using linear and logistic multivariable regression models, adjusting for location on the urban-rural gradient and other covariates. We found that household WASH was protective against high concentrations of enteric infection (four+ co-infections) at six months of age, but we did not find evidence of an association with stunting at two years. We did not find evidence that household wealth was protective against enteric infection or stunting, but wealth was associated with higher mean length-for-age Z-scores. Household WASH coverage appeared to mitigate seasonal variation in enteric infections, particularly in the dry season.

Our results can inform interventions that aim to increase WASH coverage, improve child health, and move towards health equity globally. We suggest that structural constraints to WASH access will need to be addressed to enable individual decision making around WASH that can improve child health. Pro-poor, women-oriented, climate resilient, community-level interventions that target multiple drivers of health and well-being, including poverty alleviation and housing stability, are crucial to ensure Sumak Kawsay – good living for all. Ultimately, WASH interventions should to respond to community needs and address local priorities to succeed.

El Resumen

El acceso al agua, el saneamiento, y la higiene (WASH) es a la vez un determinante directo de la salud y un determinante indirecto de muchas otras condiciones importantes para el bienestar. La carga de la salud relacionada con WASH (principalmente las infecciones entéricas y el crecimiento infantil deficiente) cae desproporcionadamente en los hogares más pobres. Esta disertación busca comprender cómo el acceso a WASH, la riqueza, y la salud infantil se intersecan en las numerosas escalas en las que opera WASH, desde el individuo hasta el hogar, la comunidad, y contextos geográficos y ambientales más amplios. Basamos nuestro trabajo en un entendimiento de los procesos sociopolíticos e históricos que han dado forma al acceso desigual a WASH y a la salud en la actualidad, y centramos las voces y las experiencias de los miembros de la comunidad y las madres como contexto crucial para nuestra investigación.

En el Capítulo 2, utilizamos métodos mixtos y un marco socioecológico para entender las preferencias y prioridades maternas relacionadas con el acceso a WASH en diez comunidades que abarcan un gradiente urbano-rural en el noroeste de Ecuador. Realizamos 33 entrevistas en profundidad con madres que participaron en el estudio ECoMiD e identificamos motivadores y restricciones al acceso a WASH a nivel individual (tiempo y trabajo), hogar (acceso a y costos de WASH), comunidad (calidad de la infraestructura), geográfico (recursos naturales, lejanía) y ambiental (impactos estacionales). Las madres dudaban en invertir en WASH sin viviendas seguras y permanentes.

En el Capítulo 3, evaluamos la relación entre la riqueza y acceso al WASH al nivel de hogar en las comunidades de ECoMiD a través del gradiente urbano-rural. Para completar este análisis, utilizamos datos cualitativos del Capítulo 2 para crear una medida del estatus socioeconómico informada por la comunidad, construida utilizando análisis de correspondencia múltiple sobre propiedad de activos. Descubrimos que la riqueza se asociaba significativamente con un mayor

acceso a WASH completo, una métrica que incluye el acceso a agua básica o limitada, saneamiento básico o limitado, e higiene básica en un hogar. Entre estos componentes, la riqueza estuvo más fuertemente asociada con un mayor acceso al saneamiento. Se identificaron umbrales de riqueza elevados para poseer artículos prioritarios de WASH.

En el Capítulo 4, probamos si acceso al WASH y la riqueza al nivel de hogar tienen un efecto protector contra la infección entérica y el retraso del crecimiento, utilizando modelos de regresión lineal y logística multivariable, ajustando por la ubicación en el gradiente urbano-rural y otras covariables seleccionadas. Encontramos que acceso al WASH protegía contra altas concentraciones de infección entérica (cuatro o más coinfecciones) a los seis meses de edad, pero no encontrábamos evidencia de una asociación entre acceso al WASH y el retraso del crecimiento a los dos años. No encontrábamos evidencia de que la riqueza protegiera contra las infecciones entéricas o el retraso del crecimiento, pero la riqueza se asoció con valores de longitud-para-la-edad Z promedios más altas. Acceso al WASH en el hogar pareció mitigar la variación estacional de las infecciones entéricas, particularmente en la estación seca.

Nuestros resultados pueden informar intervenciones con los objetivos de aumentar la cobertura de WASH, mejorar la salud infantil, y avanzar hacia la equidad en salud a nivel mundial. Sugerimos que será necesario superar las limitaciones estructurales al acceso a WASH para permitir la toma de decisiones individuales en torno a WASH que puedan mejorar la salud infantil. Las intervenciones a nivel comunitario en favor de los pobres, orientadas a las mujeres, resilientes al clima, y dirigidas a múltiples factores de salud y bienestar, incluyendo el alivio de la pobreza y la estabilidad de la vivienda, son cruciales para garantizar el Sumak Kawsay: un buen vivir para todos. En última instancia, para tener éxito, las intervenciones de WASH deben responder a las necesidades de la comunidad y a las prioridades locales.

En la historia humana, lo único que se hace desde arriba son los pozos. Todo lo demás se hace desde abajo. - Eduardo Galeano

In human history, the only thing built from the top down is a well. All the rest is built from the bottom up. - Eduardo Galeano

Levy Lab Land Acknowledgement

Our research group is primarily located at the University of Washington, which occupies the traditional land of the Coastal Salish people, including the Duwamish People past and present. We honor with gratitude the land itself and the Duwamish Tribe, while acknowledging that honor and gratitude is insufficient to ameliorate the multigenerational pain caused by the loss of those lands. I am grateful to be able to support the Duwamish as a Real Renter.

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We conduct our research on the ancestral lands of Afro-Ecuadorian and Indigenous peoples, including the Chachi, Awá, and Épera nations, whose deep-rooted presence in this region is central to its history and identity. We honor their enduring connection to the land, their unique cultural heritage, and their resilience in the face of ongoing struggles for justice and self-determination. We are deeply grateful for the opportunity to work and learn alongside them.

As external researchers in Ecuador, we acknowledge our outsider status and approach this work with a commitment to respect, humility, and reciprocity. We recognize that our backgrounds differ from those of the communities we engage with, and we are dedicated to ongoing reflection on how our positionality may shape our research practices, interpretations, and interactions. Our role is not merely to observe and document, but to build a reciprocal relationship that honors local knowledge and aligns with community priorities.

We are committed to conducting research that respects and amplifies the voices and rights of these communities. This commitment includes actively seeking community input, maintaining transparency in our methods, and addressing health and environmental inequities in ways that center the expertise and perspectives of all who call Esmeraldas home.

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Chapter 1: Introduction

Access to water and sanitation is a human right – recognized by the United Nations and codified in many national constitutions.[1,2] It is considered essential to overall wellbeing by policymakers and community members across the world. Yet the realization of this right remains unfullfilled,[3] in settings ranging from Flint, Michigan to Esmeraldas, Ecuador.

Water and sanitation access is political.[4] It has been posited that famines are a preventable and manmade calamity; the same could be said for the poor water, sanitation, and hygiene (WASH) conditions that enable the spread of enteric infections and diarrhea, the second leading cause of death in children under five worldwide.[5–7]

WASH access in historical context

Both colonization and post-colonial neoliberal policies have contributed to the poor state of public water and infrastructure in many low-resource settings.[8–11] Availability of and access to infrastructure depends in part on economic development at the national level. The state of "enforced underdevelopment" in many post-colonial countries meant that the natural development of large-scale water and sanitation infrastructure that occurred in places like the United States – which contributed to major declines in morbidity and mortality from diarrheal diseases and the eradication of hookworm – did not occur universally.[8]

The urban landscape in post-colonial countries has been heavily shaped by their colonial past.[9] WASH infrastructure developed during the colonial period was oriented primarily towards serving urban centers that were highly segregated by race and class, and led to increased marginalization of communities excluded from these services.[9,10] Rapid urbanization and population growth has often outpaced the expansion of urban service provision beyond these centers.[10] The creation and maintenance of piped water and sanitation systems is an enormous expense and can take years to complete,[10,12,13] and as a result of these historic processes, low-

income countries often lack the resources to construct the initial infrastructure and to keep pace with the demand for services among increasing urban populations.

Explicitly racist practices that originated in the colonial period have over time become entrenched under capitalism as systematized, structural forces leading to deep inequalities and poverty.[14,15] Lower-resource and marginalized communities are often forced to reside in areas that public agencies do not service or that are geographically harder to service – e.g., urban peripheries, informal settlements, on steep hillsides, in flood plains.[16] As a result, many households in both remote and urban locations in low-resource settings lack a household connection to consistent and quality piped water and sanitation.[17] Individuals seeking access to WASH are often viewed as "consumers" looking for a service, rather than citizens utilizing their rights, and demands for formal inclusion into WASH systems have in some contexts been incorporated as demands for recognition of citizenship, or "hydraulic citizenship".[18,19]

This history has played out with particular violence in indigenous Andean communities, where first the Inca and then the Spaniards began the project of taking and extracting land and resources, and private companies under neoliberalism continue the extraction process today.[11] Water, in particular, is a resource susceptible to both physical capture and contamination by private interests, through mining and other extractive industries.[20] Past indigenous relationships to land and water have been compromised by these developments, and indigenous communities are often at the forefront of movements demanding rights to water and to nature.[3,21,22]

Ecuador was among the first countries to establish the human right to water, and to recognize the rights of nature, in the 2008 constitution.[23] However, business interests are often still prioritized over citizen rights.[23] Esmeraldas, Ecuador, is one of the poorest provinces in the country. Alongside the Hispanic colonization processes described above, Esmeraldas is primarily home to an Afro-Ecuadorian population descended from freed and escaped slaves that

survived outside colonial enslavement structures.[24,25] Access to water and sanitation is limited in Esmeraldas, and racism may be one of many causes for this public service failure.

Limitations of addressing individual WASH access

The process of accessing WASH at the individual and household level is informed by historic and current political processes, as outlined above. Individual WASH behaviors are directly influenced by access to public infrastructure and household technologies,[26] and accessing WASH places an immense labor and financial burden on individuals, particularly women.[27,28] Many interventions trying to induce behavior change in the WASH field have failed, particularly around the lack of uptake of products that have been provided to households without considering local preferences or other upstream factors that impact their functionality and sustainability, or added burden placed on mothers to use the intervention.[28] Many approaches to water and sanitation service provision consider individuals as users – at best, this orients research towards what individual users need and want from WASH,[28] at worse, this orientation reinforces personal economic responsibility for obtaining resources that should in theory be a human right. The rights-based approach to water itself has been criticized as de-politicizing and as emphasizing the role of the individual over the sociopolitical factors that led to the lack of access in the first place.[3]

The conceptualization of "coping behaviors" in WASH echoes this focus on the individual. "Coping" has been defined as behaviors in response to situations of stress.[29] In the WASH field, coping behaviors are often described as something employed by individuals in the "event of" water insecurity – lack of access to affordable, adequate, reliable, and safe water.[30] In practice, this term is often used to describe anything that isn't the use of piped water, despite the fact that existing piped systems may not meet any of the criteria for water security. Further, coping mechanisms are also framed as temporary solutions, but there is little evidence to indicate that most people in low-resource settings are operating from a norm of water secure, or

are likely to under the changing future climate. Given the reality of existing socioeconomic and political structures, it could be argued that analyzing coping behaviors is simply another way of understanding the daily decisions people make, and that disconnecting these behaviors from the broader failures of public institutions to provide WASH access to their citizens does individual households a disservice.

Our research

This context underpins our decision to center the research presented in this dissertation on the lived experiences of women and mothers, and to ground it using a socioecological model which positions individuals and their WASH-related behaviors as operators at the end of a chain of broader household, community, geographic, and environmental structures that dictate opportunities and constraints. We begin this mixed-methods study by conducting qualitative research in our study community in Esmeraldas, Ecuador to understand how and why community members prioritize, purchase, and utilize WASH infrastructure, hardware, and products, across a range of community (including infrastructural and environmental) and socioeconomic contexts (Chapter 2). We use this qualitative information to guide the formation of a socioeconomic measure for the dissertation and to identify priority WASH items to include in quantitative analyses (Chapter 3). We quantitatively explore how wealth is related to WASH access under different community conditions (Chapter 3), and finally assess if household wealth and household WASH access are protective against enteric infection at six months and stunting at two years of age (Chapter 4). We understand and frame the health disparities identified in our communities, as well as the struggles vocalized by our study participants, as a result of the combined structural forces represented in the socioecological model, and we suggest that improving both WASH access and health equity will require addressing these upstream factors, as well as recognizing the central role of women and mothers in the WASH access process.

Specific Aims

Aim 1: Qualitatively explore the lived experiences managing water and sanitation needs of community members under different socioeconomic and community contexts in northwest Ecuador.

Sub aim 1a: Identify which key household assets and key WASH products and hardware are financial priorities for community members.
Sub aim 1b: Explore how community members prioritize, purchase, and utilize WASH infrastructure, hardware, and products to maintain health.
Sub aim 1c: Contextualize the quantitative findings from Aim 2 and Aim 3 with qualitative information.

Hypothesis: Priority household assets and WASH products and hardware will vary by socioeconomic and community context, but some asset and WASH priorities will be consistent in the population.

Aim 2: Quantitatively assess variation in household WASH access under different socioeconomic and community contexts in northwest Ecuador.

Sub aim 2a: Explore how SES and WASH access vary across different community contexts and if household SES is associated with household WASH access.
Sub aim 2b: Explore potential thresholds of wealth needed to obtain key WASH products and hardware identified in aim 1a.

Hypotheses: Higher SES households will have greater WASH access, and both SES and WASH will vary across and within communities; More remote areas will tend to have lower SES scores and have less safe WASH; WASH products and hardware will have a relatively high threshold of wealth needed to obtain them.

Aim 3: Estimate the effect of household WASH access and household wealth on enteric infection and child growth under different community contexts in northwest Ecuador.

Sub aim 3a: Estimate the relative effects of household WASH and household wealth on child enteric infection and child growth.
Sub aim 3b: Explore if WASH and wealth or WASH and season interact to affect health.

Hypotheses: Household level WASH will have a smaller protective effect against enteric and poor growth compared to household wealth; the protective effect of safe household WASH will be even lower or absent among low SES households.

Chapter 2: Socioecological drivers of WASH choices: A qualitative analysis of maternal perspectives in northwest Ecuador

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ABSTRACT

Introduction: Household-level water, sanitation, and hygiene (WASH) interventions do not always achieve expected health benefits. Research that considers WASH within a socioecological framework where environmental, infrastructural, economic, and individual factors are interconnected can help explain why. Community perspectives can also inform development of WASH interventions and overcome barriers to WASH access and use.

Methods: To understand preferences and priorities related to household WASH under different socioeconomic and community contexts, we carried out a qualitative analysis as a piece of a larger sequential mixed-methods study in northwest Ecuador. We conducted in-depth interviews and freelisting activities with 33 mothers of children under two years of age participating in the ECoMiD study, purposively sampled across an urban-rural gradient. Data were primarily inductively coded, and codes were connected thematically with elements of the socioecological framework. Select survey data from ECoMiD were analyzed to provide additional context.

Results: Maternal WASH choices are driven by factors at each level of the socioecological framework. Environment: location of residence on the urban-rural gradient has mixed implications for WASH access, based on distance to piped systems and rivers. Community: infrastructure quality influences maternal WASH preferences and dictates coping behaviors. Household: consistent, high quality piped water for drinking and chores is the most common maternal WASH preference in the home, but WASH utilization and purchasing priorities respond to broader financial and labor-related constraints. Individuals: mothers value time-savings associated with WASH technologies and access. Cross-cutting: seasonal conditions limit or facilitate WASH access for different technologies. Water for hygiene was considered essential. Mothers expressed unwillingness to invest in expensive WASH technology in households they did not own, or that were in informal settlements or flood prone areas.

Discussion: Maternal decision making operates at the terminus of a chain of broader socioecological conditions. The financial and labor burden of obtaining WASH access is greatest for the poorest households with the least community infrastructure, compounded by seasonal conditions. Decisions to invest in WASH hardware depend on home ownership status and location of the home. Improving structural drivers of WASH access would better meet community needs and support mothers in making WASH-related choices that can ultimately improve child health and wellbeing.

INTRODUCTION

Despite their potential for providing important health benefits,[31–35] recent large-scale household water, sanitation, and hygiene (WASH) interventions have had limited success in improving child health outcomes.[36–39] This may be partially explained by a lack of understanding of individual and community priorities, limiting acceptability and uptake of interventions.[28] It may also be explained by an insufficient focus on upstream factors that impact household access. WASH is increasingly recognized as a complex set of interventions managed by diverse authorities[40] that encompass multiple domains, including environmental resources, community-level infrastructure, household-level hardware, and individual-level behaviors. Yet less is known about the interplay between these domains – for instance, how the effectiveness of different household-level WASH interventions are limited or facilitated by community or environmental conditions, or by a household's socioeconomic resources.[41,42]

Socioecological theory considers individual health outcomes to be linked directly to larger societal and structural factors as well as to biological exposures[43,44] In the WASH context, individual health outcomes, such as infection and child growth, are interconnected with household, community, and broader environmental and socio-political contexts. A socioecological framework is particularly important for considering why existing interventions that focus only on individual behavior change or on household-level improvements in isolation may fail to produce expected health results.

The identification of specific drivers of WASH-related decision making ("choice") can help to illuminate the most important aspects of the larger domains within which individuals act to access WASH resources. There is a lack of existing frameworks for understanding drivers of water choice, in particular, that incorporate time, labor, cost, community infrastructure, natural resources, seasonal effects, and sanitation needs comprehensively in low-resource settings.[45]

Current conceptualizations of the value of WASH focus on the ability of a WASH resource (product, hardware, infrastructure) to ultimately provide a health benefit to individuals by reducing exposure to enteric and other related infections. Although WASH research has increasingly also recognized other benefits of WASH access, such as privacy, dignity, safety, and quality of life,[46,47] as well as the importance of gender equality in WASH,[27,48] global WASH targets for monitoring progress towards the Sustainable Development Goals,[49] are still primarily oriented towards indicators focusing on reducing risk of infection. [50,51] There have been growing calls to incorporate the perspectives of the individuals who use WASH into water quality and treatment product research,[28] as well as to develop alternate WASH service ladders that prioritize service aspects most valued by these individuals[52,16] More recent research has begun to take a social-justice oriented approach to understanding disparities in water access.[53] By expanding the focus beyond the role of the individual, researchers can better meet community needs that go beyond specific health concerns and consider health and well-being more holistically.[16]

Despite these trends, recipients of WASH interventions are not typically consulted on their needs or preferences, which has important implications for suitability and sustainability.[40,54] Community members are best equipped to identify drivers and constraints of WASH choice, and community voices are an important source of insight to guide improved intervention approaches. Understanding community member motivations behind individual WASH behaviors can provide important insights on upstream barriers not readily identifiable through quantitative analyses of WASH-related exposures alone.

In this study, we use qualitative data generated as part of a larger mixed-methods study in northwest Ecuador to understand intersectional drivers of WASH choice across multiple levels of a socioecological framework: environment, geography (urban-rural), community, household, and individual. In-depth interviews with mothers of children under two years of age living in ten

communities across an urban-rural gradient captured a range of wealth, geographic, and community infrastructure contexts. We used a combination of open-ended questions and freelists to better understand how individuals purchase, prioritize, and utilize WASH as one of many priorities in their lives. We also summarized select survey data collected from the households participating in the larger ECoMiD study to provide additional context. Our results can inform future intervention approaches that address upstream constraints to maternal WASH choices and enable healthy WASH behaviors.

METHODS

Study design

This qualitative analysis was conducted in conjunction with an ongoing prospective birth cohort in northwest Ecuador, the 'Enteropatógenos, Crecimiento, Microbioma, y Diarrea', or ECoMiD study (in English: enteric pathogens, growth, microbiome, and diarrhea).[55] Select ECoMiD survey data were included in this analysis to inform the sampling frame and to provide additional context for the results.

Background and study setting

We selected interview subjects from among households already participating in the ECoMiD study.[55] In the parent study, the research team recruited 521 mother-child dyads to join the ECoMiD study in northwest Ecuador. ECoMiD field workers recruited subjects across an urban-rural gradient made up of several small rural villages, some accessible by road (pops. 400-920) and referred to here as "rural-road" communities, and others primarily accessed by river (pops. ~200-700) and referred to here as "rural-river" communities. The gradient also includes the mid-sized town of Borbón (pop. ~4,500), referred to as "intermediate", and the larger city of Esmeraldas (~pop. 150,000), referred to as "urban". Mothers were recruited at the end of their pregnancy and followed until their children turned two; each household was visited 10 times throughout the study. ECoMiD field workers carried out surveys and spot checks in ECoMiD households that provided data on WASH conditions (toilet type, water type, handwashing station, water storage containers), socioeconomic conditions (household assets, housing materials, maternal education), and demographic information (sex, age), among other topics.

The province of Esmeraldas where the study takes place is primarily Afro-Ecuadorian, with a substantial indigenous population, and is among the poorest provinces in Ecuador.[56,57,58] Most of the communities participating in ECoMiD are located along the Cayapas, Santiago, Onzole, or Esmeraldas rivers, which provide important sources of water, food, and transport. The

communities also experience regular exposure to extreme-weather events, such as flooding and landslides due to heavy rainfall that has worsened in recent decades with the changing global climate.[59,60,61,62]

Community infrastructure. Public piped water systems of varying age, quality, and consistency have been installed in the urban site, Esmeraldas, the intermediate site, Borbón (plant constructed in 1990 and last upgraded in 2006), and the rural-road communities of Timbiré & Selva Alegre (shared and newer system), Maldonado (older system with poorer perceived quality), and Colon Eloy. A public project to install a piped water system in some of the rural-river communities – Colon de Onzole, Santo Domingo, and Zancudo, but not San Francisco – was under construction but not yet operational as of October 2024. Pipeline supply and pressure vary by proximity to plant and elevation, among other physical factors, and so constraints to use can vary both within and between sites.[63,64]

Many of the water systems are community-financed, with household payments directly supporting system maintenance. However, there are inconsistent enforcement mechanisms for payment, and non-payment practices may leave such community systems underfinanced, especially without sufficient support and investment from regional and national authorities.[65]

Household water management. Within ECoMiD communities that have public water systems, access to piped systems at the household-level varies. Households in informal settlements (built without government permission, often in flood or landslide prone areas or on otherwise less desirable land that may be difficult to connect to public services), households on the edges of urban areas, and households in rural areas where no piped systems exist are the least likely to have a household connection.[63]

Community sanitation systems. A sewer system with treatment plant is in place in the urban site of Esmeraldas. The intermediate town of Borbón has a fluvial sewerage system for grey

water that discharges directly into the river. Fluvial drainage sewerage has also been installed in parts of some communities, such as Maldonado (rural-road), as a part of housing provided by the “Ministerio de Desarrollo Urbano y Vivienda” (MIDUVI), but the drainage pipes are not connected to any larger system. There are no sewer systems in place in the rural-river communities. Households in the communities without sewerage systems for processing black wastewater typically rely on septic tanks or soak pits, and use large buckets stored in the bathroom and shower areas to flush toilets and bathe.

National context

Ecuador has experienced increasing sociopolitical instability and violence since 2020,[66,67] with an influx of international narcotrafficking groups and growing levels of corruption in the government, including in the institutions responsible for providing public services such as WASH infrastructure.[68] The province of Esmeraldas already suffers from a lack of investment and maintenance for public projects,[24] which is likely to continue under the current context. In addition, planned power cuts lasting up to 12 hours a day several days a week are increasingly common across Ecuador in response to energy sector deficiencies and droughts.[69] Because many WASH systems, like pumps, depend on electricity, cuts to power also mean cuts to water and/or sanitation services in much of the country.

Data collection: interview tool development

Each interview included open-ended questions as well as two freelisting activities intended to gather additional information. Open-ended questions covered conceptualizations of wealth and of differences in social classes, difficulties and solutions for accessing WASH, seasonal differences in WASH access, and individual and community priorities, among other related topics. In the first freelist activity, the participants were asked to identify, in any order, the most important objects they or their family needed to 1) get drinking water, 2) get water for chores,

and 3) to keep their house clean and hygienic, including feces management (complete interview guide provided in the Supplemental Materials). In the second freelist activity, participants were asked to list, in any order, the most important items they owned, of any type. Finally, participants were read and shown an extensive list of WASH-related products, hardware, and technologies and asked which would be priorities that they would want to add to their homes and why.

We pilot-tested the interview-guide with seven fieldworkers across the urban-rural gradient and adjusted in response to their feedback. Due to instability in the city of Esmeraldas, we trained two female ECoMiD fieldworkers already based in the city to conduct the interviews with the eight households for that site. The trained fieldworkers observed MKMP conduct an interview and each conducted one under observation before commencing their independent interviews, and a debrief was conducted at the conclusion of their work.

Data collection: recruitment and interviews

A stratified purposive sample[70,71] was drawn from the ECoMiD cohort, where the unit of analysis was the mother or primary caretaker of a child <2 years of age who was currently participating in ECoMiD, representing the household To capture maximum variation in the sample, households were stratified by socioeconomic status (SES) and geographic location on the urban-rural gradient for inclusion (see Supplemental Table 1. SES was determined using multiple correspondence analysis on asset ownership for each household as calculated previously). All participants were approached by local Ecuadorian fieldworkers working for ECoMiD for inclusion in the additional interview activity, and asked to sign an additional consent form including consent to audio recording. All participants who were approached agreed to participate, and no repeat interviews were conducted. The final sample consisted of 33 households. This size is considered sufficient to achieve a diversity of perspectives and to have the necessary information power to address the research question.[72]

We conducted semi-structured in-depth interviews[73] in Spanish with 33 primary caregivers from November 6-16, 2023 (Supplemental Table 2). During each interview, the U.S. researcher (author MKMP) was accompanied by a local ECoMiD project member and/or fieldworker familiar to the mothers. Fieldworkers contacted the participants in advance and we conducted the interviews during the day in the participants' homes. Interviews lasted between 30-60 minutes, averaging approximately 45 minutes. We recorded each interview on a small portable recorder, and an Ecuadorian transcribed the interviews verbatim (in Spanish) in December, 2023.

A preliminary memo was written by MKMP on positionality and potential pre-conceived notions and biases prior to initiating fieldwork, fieldnote memos were recorded by MKMP at the end of each day of interviews reflecting on the process and findings, and a reflective memo completed by MKMP at the conclusion of the fieldwork. Memos were incorporated during the analysis stage.

Data analysis

Coding: After an initial read-through of the complete transcripts, the coder (MKMP) inductively coded[74] text from the interviews in Atlas.ti.[75] Predetermined structural codes related to the socioecological framework, such as "community WASH" and "household WASH" were also utilized. In vivo codes were used if a phrase captured a key shared expression among interviewees best captured in their own words.

The coder (MKMP) maintained a codebook (Supplemental Table 3) with a complete description of the definition for each code. Although only one researcher independently coded the data, the codebook and initial categories and themes were shared early on with project team members, including field team members in Ecuador, as a form of peer debriefing and triangulation. Participants were not asked to review their transcripts to avoid placing additional burden on the mothers. Coding was completed in March, 2024.

Analysis: We followed recommended practices for thematic analysis:[74] analytic memos were used to identify patterns and categories and to relate the codes and themes with the research questions and the socioecological framework.[76,77] Data processing was conducted primarily through metacoding and cutting and sorting[78] facilitated by Atlas.ti software.

Key methods for pattern identification included comparison of codes and categories between 1) mothers living in different communities along the urban-rural gradient and 2) mothers in different strata of socio-economic status, as determined in the initial sampling frame (Supplemental Table 1). Comparison was also made between individual, household, community, geographic, and environmental WASH factors. Findings were presented to and discussed with members of the field team and study team for peer debriefing. After themes were determined, the text of the transcripts was revisited to ensure representativeness and accuracy of the themes as a reflection of the data. Freelists were analyzed using a simple count method to tally the frequency of responses.[76,79]

Data protection and ethical approvals

Interview transcripts are stored in a password protected cloud folder hosted by the University of Washington. All data are saved using unique household identifiers, and any names or potentially identifying information were removed from the final the dataset. A file linking the household IDs to identifying information is available to the ECoMiD study team, and saved in a separate password-protected cloud folder with restricted access.

The ECoMiD study has oversight and approval from institutional review boards at the University of Washington (IRB 00014270) and Universidad San Francisco de Quito (2018-022M), and was also approved by the Ecuadorian Ministry of Health (MSPCURI0002534). The study was originally approved in the United States by Emory University (IRB00101202). All interviews conducted as a part of this project were approved under existing IRB protocols and

all participants signed a separate consent form to participate, including consent to audio record and store de-identified data.

Analysis team and positionality

The authors acknowledge that our participation in the development of the research question, the undertaking of the research process, and interpretation of findings will be influenced by our positionality. For MKMP, this includes being a white U.S. doctoral candidate and mother of a child under five, fluent in Spanish but not a native speaker, who has periodically lived throughout Latin America, but never resided in Ecuador. Our partners, collaborators, team members, and study participants in Ecuador provide essential knowledge to inform the research project.

RESULTS

We conducted a total of 33 interviews across the ten communities, eight in each community type along the urban-rural gradient and one additional in the intermediate site during team training. Mothers interviewed ranged in age from 18 to 39, with a mean age of 27 (Table 1). There was over-representation of households in the middle wealth tertile (46%, compared to 24% in the poorest and 30% in the wealthiest). Mothers in the rural river sites were older, on average, and had completed less schooling overall compared to mothers in more urban sites, although this reflects the population in each of these sites. Freelisting results, key themes, and illustrative quotes from the qualitative data analysis are presented below in alignment with the socioecological framework (Figure 1).

Freelisting results

Overall, purchased bottled water was the most frequently freelisted item as important for obtaining drinking water (70% of interviewees, Table 2), Rain water, river water, and piped water were the most common items listed as important for chores. Mothers also discussed purchasing well water from neighbors for this purpose. A number of household water storage container types (e.g., tanks, drums) were also listed frequently as important for both drinking water and chores (Figure 2).

There was variation by site: Intermediate site residents most often listed purchased bottled water as important for drinking (89%) (Table 2). The rural-river sites most frequently listed rainwater as important (88%), while in the urban site mothers listed piped water (63%) and purchased water (50%) as important, but not rain. 38% of rural-road interviewees listed piped water as important overall, compared to 75% listing purchased water and 25% listing rain water.

Rain water was most frequently freelisted as important for chores in the river communities (listed by 100% of mothers in that site). In the rural-road communities, piped water

was most frequently listed as an important source of water for chores (88% overall), while in the intermediate site most households listed rainwater as important for chores (78%), and in the urban site most listed tanks (no specified source, 63%) and pipes (38%).

Chlorine was the most commonly listed item needed for keeping the household clean, including feces management (58% of mothers overall), but was listed less frequently as important for drinking water (12% of mothers overall) or water for chores (6% of mothers overall) (Table 2). Water was the third most frequently listed item as important to keep the household clean (24% of mothers overall), after chlorine and disinfectant.

Cisterns were by far the most common response to household WASH priorities (selected by 66% of mothers overall, ranging from 44% in the intermediate site to 100% of mothers in the urban site), followed by bathrooms (selected by 45% overall, ranging from 13% in the urban site to 67% in the intermediate site). More than 10% of mothers also selected piped water, showers, pumps, and filters or purifiers as priorities to purchase or install.

Environmental scale: Both rainy and dry season conditions affect WASH access

In the dry season, access to water sources becomes more limited in all ECoMiD communities. The river shrinks in size, becoming more distant and difficult to access, and rains lessen, providing a much less frequent source of water. Many mothers reported having to rely on less-preferred water sources during the dry season, and having to work harder to access their usual sources.

> *"It is difficult to fill up your water [containers]… from here, you have to go and fill the buckets, and you get tired, sometimes it doesn't rain, and there is no money to buy water, it is hard."* ***HH 11***

> *"It is difficult when it is the dry season, those who have water, we have to ask them to fill a tank for us, and they charge a dollar fifty for the tank when it doesn't rain. But when it rains, then even with my [injured] leg I go outside and try to fill my tanks and buckets."* ***HH 7008***

However, in the wet season, when rains are more frequent, heavy rains can lead to flooding and cause the rivers in the region to overflow. Many mothers expressed an unwillingness to install expensive household WASH hardware like cisterns in areas like the rural-river communities, where flooding events are common and likely to contaminate stored water. Mothers from rural-river communities talked the most frequently about flooding in the interviews (Supplemental Figure 1).

Geographic scale: Location on the urban-rural gradient has mixed implications for WASH access

Despite the larger extent of public WASH infrastructure available in the more urban locations of the gradient, mothers in the urban site often struggled with water intermittency, and expressed a desire for household water storage options like tanks and cisterns to increase reliability of their water supply. Even households that have a piped connection to public water do not always report using it as their main source of drinking water. Among the households that participated in the interviews, less than a third reported piped water as their main source of drinking water, while almost half had access to a household piped connection (Table 1). Households use a range of other drinking water sources, including bottled water, rain water, river water, wells, and public taps, and store water in containers of varying size and capacity (Figure 2). Large water tanks and cisterns provide the greatest volume but take up valuable space, while smaller containers like jerry cans and buckets must be refilled often. Bottled water tends to be more expensive when purchased in smaller containers at greater frequency. In the intermediate site, a number of study households were located in informal settlements without access to the public piped system. Many mothers, particularly in the intermediate site and rural-road communities, described the piped water that was available as too dirty to be used for drinking, though piped water was often described as useful for chores (washing floors, clothes,

dishes, bathing, cleaning the bathroom, etc.). Mothers in the rural-river communities lacked access to any piped systems, but described easy access to rivers as a benefit.

> *"Sometimes in the city, you might go without water for three, four days, but here at least from the river we have access to water all the time"* ***HH 7010***

Community scale: Infrastructure quality influences maternal WASH preferences and dictates coping behaviors

The perceived quality of water sources differed across communities within the same geographic area due to infrastructural variability. For instance, the water treatment plants in the rural-road communities of Selva Alegre and Timbiré are newer and tended to have high perceived quality compared to those in Maldonado and the intermediate site, where the treatment plant is quite old and water quality and acceptability[80] perceptions are very poor.

> *"[I would like] the water to come out cleaner, because sometimes it comes out brown, like river water, it comes out dirty."* ***HH 2125***

Although the ECoMiD study does not collect data on user satisfaction with water, adequate water access has been defined in terms of availability, accessibility, acceptability, and quality, where acceptability is defined by color, small, and taste, and quality is determined by health risk.[80] Availability also varies by community,[63] particularly in terms of intermittency of access, with implications for which community members need to consider alternatives and backups during outages to piped systems.

Household scale: Reliable, high-quality piped water is the maternal WASH preference at the household level, but WASH source prioritization responds to a number of broader constraints

Mothers often expressed a desire for access to clean, drinkable water consistently and easily available in their homes for all uses – consumption, cooking, and cleaning. Typically, this access was envisioned as a part of a piped water system.

"[I would like to have] clean water where you can just turn on the hose and see clean water that you don't have to store… I could use it for the bathroom but also to drink." ***HH 3117***

In practice, mothers change their primary water sources based on intended use (drinking vs chores), season, and other conditions, and do not rely on a single source. Mothers described a hierarchy of preferred water sources in response to constraints (Figure 3).

"When it rains hard there are people who collect their rain water, and when it doesn't rain, they use their piped water, and only when that is broken and empty, then they go to the river to collect their water, or they go and ask [someone] to fill their water." ***HH 3207***

"To get water when it rains, you can collect rain water, and when you are in a time when it isn't raining, you have to go get water from the river and boil it, or you have go and buy your bottle of water." ***HH 7008***

Water for cooking fell into a middle ground in terms of distinguishing between preferred water sources, with some mothers expressing that "dirtier"/less preferred water sources could still be used in cooking, and others noting that they would only use bottled water for cooking.

"In rich households] the water is treated and here in the middle class, for example we have to buy one kind of water to be drinking, and they use the same water for everything because their water is better treated, and ours, if we are talking about the tap water, we can't use it to cook, we have a specific type of water to cook and another kind of water to do chores or clean." ***HH 2414***

Many mothers described cisterns, elevated tanks, or wells connected to a tubing system and pump in the home as valuable when there was no access to piped systems or when that access was unreliable. In the open-ended interview questions, mothers focused primarily on cisterns as a preferred water storage option, and cisterns were mentioned the most frequently as a WASH priority.

"With a cistern you fill it up, and if there is no water you have your water, you don't go without." ***HH 3207***

However, cisterns were considered to be very expensive and difficult to obtain. In addition, mothers frequently discussed the labor needed to maintain them.

Storage and labor constraints

Mothers frequently described collecting river and rain water (and piped water, when systems were inconsistent) and storing it in the household in a variety of containers, from buckets to cisterns (Figure 2). The labor of collecting river and rain water, and particularly of transporting river water to the home, was a major focus of many of the interviews. Mothers valued the amount of storage space available in a given storage container because it reduced the frequency with which they needed to collect water. However, once stored, mothers described the burden of keeping the water clean as another time- and energy-consuming activity.

Mothers often mentioned the labor associated with maintaining clean water in cisterns, the top priority WASH item. Cisterns can also pose a risk for arboviral diseases, as they can provide breeding grounds for mosquitos if not properly maintained.[81] Several mothers described the necessity of treating the water using larvicides such as Abate (often distributed for free by the government as a part of dengue prevention efforts) as a part of the associated labor:

> *"Really, we have to be the ones to treat the water [in the cistern], and to put in the abate and be the ones to be continuously cleaning it, because sometimes the water… cockroaches can get in there… frogs… and sometimes you don't realize, this water is running all through your house and you think it is well treated, but it isn't… you have to be cleaning it continuously to make sure you have water security."* ***HH 2414***

> *"It would be better if the water came directly from the tap, and I didn't have to have a cistern, because sometimes the water in the cistern sits for a long time… so you have to be cleaning it, and keep it clean, it isn't good that the water is like this, it would be better if the water came directly out of the tap."* ***HH 2125***

Mothers also expressed hesitancy to invest in expensive WASH solutions like cisterns in a house they didn't own, be it a rental, a family member's home, or a house in an informal

settlement. Mothers also described space or geographic limitations as barriers to constructing cisterns.

> *"Interviewer: Why don't you want to build a cistern here?"*
> *"Mother: because it isn't my house"* ***HH 3207***
> *"Mother: because there isn't an adequate place to put it"* ***HH 4012***
> *"Mother: because the terrain does not lend itself to excavations, it is all pure rock below"* ***HH 4014***

Financial constraints

When asked about the most difficult part of managing their WASH needs, many mothers expressed that they did not have enough money to manage the amount of water they needed to buy for drinking and for household chores. This issue was discussed most frequently by mothers in the intermediate site (Supplemental Figure 1). Households that relied on purchased water discussed having to buy large bottles or tanks multiples times a week, and sometimes you just *"don't have those three dollars"* [HHs 2031, 2331]. Some mothers recognized that buying bottled water might be more affordable in the short term, but was ultimately a less economic solution than buying larger tanks, constructing hardware, or making monthly payments for piped access:

> *"[Bottled water] might be cheap in the short term, but long term it is expensive buying bottled water, because for example, I buy enough for a month, that makes it easier for me, I don't have to buy it every day… short term it is cheap but long term it is expensive, if we calculate how much we spend [on water] in a year, but I think bottled water is the most accessible."* ***HH 3124***

Often, when describing differences between rich and poor households, mothers would describe poor households as needing to be purchasing resources all the time, while rich households "*have everything" ("tengan todo")* and don't need to expend time and effort every day to obtain WASH resources.

> "*They [the wealthy] have more possibilities for getting water, everything we don't have here, they have everything there, here we have to go and buy and look [for water] every day, but there, they don't buy [water] every day, they pay monthly, while here we*

have to pay every day, and when the tank runs out you have to buy another." ***HH 2237***

Many mothers expressed that having clean piped water would alleviate many of these daily costs and time burdens, but mothers also described being unable to afford the monthly cost of getting piped water even with a connection. Similarly, WASH items such as cisterns, elevated tanks, and wells were often identified as appealing, but unaffordable.

"*If I had it [the money], of course, why wouldn't I want it [a cistern]."* ***HH 2031***

Mothers also described paying children or other community members to collect water for them, or purchasing water from vendors on the street.

Individual scale: Mothers prioritize time-savings associated with WASH access

Mothers often discussed prioritizing WASH-related purchases in relation to the time-saving benefit that easier access to water or sanitation in the house provides, particularly as a means to free up time for childcare. For instance, household assets such as washing machines were considered valuable in that clothes washing could take place in the home with children present (Figure 1). Similarly, having onsite access to water was often discussed as being valued because it averted the need to leave the home, with or without young children, to collect water. Conversely, many mothers discussed prioritizing purchasing, boiling, or treating water for their children's consumption, despite the additional cost, time, and labor required to do so.

We also noted some cross-cutting themes that impacted results at multiple scales.

Perceived constraints to sanitation access centered on water access

We included several questions on feces management in the qualitative interviews, but mothers were hesitant to address issues related to feces directly. However, there was a general consensus that water is a necessary tool to enable households to maintain a clean and hygienic environment.

"In order to have a clean and tidy house, you have to have water, if you don't have water, what else can you do except sweep, how can you clean the bathroom?" ***HH 1046***

"Agua es lo primordial" ["Water is essential" repeated by many HHs] –

"Water is the most essential in order to keep the house clean" ***HH 1149***

Most mothers in our study reported owning a toilet that connected to a sewer or septic tank, or to a pit (Table 1). Few households reported using unimproved sanitation facilities and just two households reported sharing a bathroom with another household. There was a general perception among mothers that household sanitation facilities (primarily septic tanks) were sufficient and without issues – the main issue identified was that water was needed to clean and manage the toilet (e.g., to flush). Mothers did not express concern about their septic tanks filling up or overflowing as long as they could be covered. Some mothers identified sewers as community-level priorities that they would like the government to invest in – but almost always secondarily to playgrounds for children, sports fields, and improvements to roads.

DISCUSSION

Our qualitative research suggests that mothers respond to numerous constraints and opportunities at the individual, household, community, and broader environmental level when making choices about which water sources to consume or utilize, and which WASH products and hardware to invest in (Figures 1, 3). Orienting our analysis around a socioecological framework enabled us to move beyond a narrow focus on individuals and households to consider drivers of WASH choice at multiple scales. We found that constraints related to maternal water choice tend to layer together and overlap, particularly in the lower-preference water sources like rain water and river water, which require labor and storage space and can be more difficult to access or keep clean in both rainy and dry conditions (Figure 3). Higher preference water sources, like piped water and purchased water, had fewer perceived constraints (primarily intermittency and cost, respectively).

Drivers of water choice specifically for chores tended to focus on ease of access over quality, as the water did not need to be fit for consumption. Conversely, drivers of water choice specifically for children tended to focus on quality. Cisterns were frequently mentioned as desirable WASH hardware, but have high financial and labor-related installation costs, in addition to being susceptible to flood events. Coping behaviors, such as purchasing or boiling water, were sometimes discussed as options used to overcome broader constraints, but necessitate additional financial or labor expenditures. Higher-level public investment in infrastructure, equitable economic growth/employment, and housing are needed to support individual WASH-related decision making and to improve related health behaviors and outcomes.

Drivers of WASH choice

Environmental drivers

The seasonal impacts of dry and flood conditions dictated maternal WASH choices in different sites in our study. Year-round water scarce conditions are growing more common, and such scarcity in both access to piped and rain water has been connected with increased use of WASH coping behaviors in Mexico and elsewhere.[82,83] Coping mechanisms are generally estimated to be more costly than access to formal infrastructure,[84] and so increasing water scarcity is likely to drive increased household WASH expenditures. Extreme weather events and heavy rainfall are also expected to increase with climate change.[85] Stored water and sanitation systems are both vulnerable to flooding, and while contamination of a stored water source can harm an individual household, contamination from sanitation overflows expands to the community level. Recent research has found that the impact of WASH interventions on health can vary by season,[86–88] underscoring the importance of better understanding this driver.

Community drivers

Water availability and quality at the individual and household level is largely determined by infrastructure available at the community level. We found high levels of variation in quality, acceptability, availability, and accessibility to public infrastructure across and within our urban-rural study sites, and these factors dictated the parameters of maternal WASH choice. The cost of constructing WASH infrastructure at the community level is typically too high for individual households or even communities to construct without financial support from higher levels of government or non-profit assistance, and even at the government level, resources for WASH services are often insufficient.[89] Urban centers tend to have at least some municipal services, and some larger rural communities may receive support to develop community managed systems, but very small and remote rural communities lack support from governmental, private, or non-governmental institutions for infrastructure investment.[90,91]

The piped water access provided to households by community infrastructure is particularly important in increasing the ease of access to large quantities of water. Perceived quality of piped water modified mothers water choices differently for consumption and for chores. Water used for hygiene has indirect benefits on health,[32] and even contaminated or intermittent piped water can provide important reductions in the labor of water collection. In communities without pipes, purchased water, rain water, and river water were the only options for water access, and purchased water was considered as important for drinking but not for chores in those communities, likely reflecting poverty as a barrier to expenditures.

Intermittency in piped water systems has been found to erode community trust and increase reliance on the use of alternate water sources, and a recent study in three of the ECoMiD communities found that intermittency increased reliance on bottled water as the only source of drinking water.[63,92] Prior research also found high rates of bottled water purchasing among poor households in the rural-river communities that lack access to any community infrastructure, in place of home treatment methods.[92] Despite the household expense, increasing reliance on bottled water linked to failed public service provision is a trend across low-resource countries.[93] Concerningly, water testing conducted by our team and others has found that large reusable bottled water sold in Ecuador can also be contaminated with coliforms, consistent with other global findings.[94]

Another infrastructural driver of water choice is access to electricity. When the power is out, household technologies that depend on tube and pump systems, including to draw water from wells and cisterns, are not able to distribute water throughout the household. The high costs of providing large-scale electrification programs, particularly in rural areas, present a similar challenge as those for constructing large water distribution and sewage systems. Off-grid solutions, such as decentralized grids or smaller, local solar or hydroelectric projects, have been proposed as community-level alternatives for access.[95,96] However, droughts in the region pose

a risk for relying on hydroelectric power, and in 2024, droughts led to widespread electrical outages across South America, including in Ecuador.[69] Mothers in our study described storing piped and other water in response to planned or predicted outages to cope with these conditions. WASH solutions provided by governments or via interventions must be able to overcome these infrastructural challenges.

Household drivers

Labor and costs were major drivers of maternal water choice for both consumption and chores in our study. These findings are in line with prior research on drivers of food and water choice and coping practices.[30,83,97–102] Household production theory considers the cost of food consumption as the sum of price and value of time requirements to procure and cook foods.[99,100] Similarly, water costs may include purchasing bottled water, paying someone to collect water, paying for monthly piped water access, paying for fuel or materials to treat water, plus the time and labor costs to collect, store, and treat water from rain or rivers. Both types of expenditures were important and consistent themes expressed by our study participants as burdens that they experienced.

Household technology has also been put forward as an additional determinant of choice.[99,103] In the water realm, technology would be hardware such as cisterns, toilets, water tanks, pumps, and wells that households can purchase or construct. We identified hesitancies in mothers to invest in expensive WASH technologies particularly in houses they did not own, and in informal settlements. Unwillingness to invest in houses in informal settlements is a barrier that was identified as a major constraint to wealth generation in Latin America by Hernando de Soto[104], who promoted legalization of informal settlements as the path towards economic growth and poverty alleviation. In the absence of formal home ownership, local WASH non-governmental organizations in the area have suggested that affordable, temporary alternatives, such as large, transportable plastic tanks, could be a potential solution, but more research with

individuals and communities is needed to ascertain if households would want to invest in something more immediately accessible but possibly of perceived lower quality/durability compared to long-term hardware solutions (Personal Comms, Green Empowerment/Sam).

Individual drivers

Our findings that mothers are consistently making tradeoffs through their WASH utilization, purchasing, and investment is consistent with existing literature.[30,83] In the context of water choice in low-resource, high-contamination settings, risk of infection is a key part of these tradeoffs. [105] In many instances in the interviews, mothers expressed an awareness that they were making these choices. The frequent discussion of purchasing, treating, or boiling water for young children indicates there is maternal willingness to expend extra time and/or money in order to achieve perceived health benefits, particularly for this vulnerable age group.

Mothers in our interviews also used social capital to overcome constraints to water access,[106] by borrowing water or toilet access from friends, family, and neighbors. Water and toilet borrowing are common coping mechanisms that do not require financial expenditures,[106] but which have been connected to increased stress[30]. As such, social capital is an important individual resource, particularly in the absence of financial capital.

Intersectional drivers

Money presents households with the means to overcome infrastructural and seasonal constraints to water access. This highlights the ways in which lack of access to WASH burdens the poorest households the most – poor households are already less likely to have access to public WASH connections,[50] and the poorer quality that access is, the more likely that a household will need to expend additional money or labor to access alternate water sources. The burden of obtaining WASH access globally are highest on the poorest,[82,102] and coping costs, financial and labor-related, place the largest burden on the poorest populations.[102,107] Weekly

purchasing of water requires both time and money, and increases unpredictability[82] and stress,[108] as reflected in our interviews, with likely biological consequences. Installation costs for cisterns, tanks, and other hardware that could maintain access in the face of intermittency or low-quality piped water were high, and perceived as insurmountable in by many of our study participants. Seasonal droughts and flooding compounded the financial burden on households to purchase or expend extra labor to acquire water, particularly in the rural-river communities without infrastructure. Yet the burden placed on the poorest exists across the urban-rural gradient, due to the variation in infrastructure quality and consistency described above. Infrastructure that is accessible, reliable, and high quality can help reduce the burden on households across wealth levels.

Connecting drivers of WASH choice to health

Mothers in our interviews generally discussed a range of water sources considered and used in response to different constraints and for different purposes. The use of multiple drinking water sources is one practice often identified by studies looking at coping strategies – much like households that practice stove and fuel "stacking",[109] households without access or with limited/intermittent access to clean, sufficient, affordable drinking water are likely to layer less-safe forms of consumption on top of cleaner sources, increasing exposure opportunities.[110] On the other hand, in these intermittent access contexts, households without back-up water sources risk completely losing access to water during outages.

Many mothers suggested that there are limited safe drinking water choices available to even the wealthiest residents in our study sites. As such, it is possible that the majority of the ECoMiD households face similar levels of exposure to unsafe drinking water, but the poor are expending more of their resources to access that water.[102] These expenditures may leave the poorest households more vulnerable to other interconnected challenges of poverty, such as food insecurity and unequal access to electricity, and increase the cumulative risk of poor health

outcomes, such as growth shortfalls and stunting. Though the health benefits of improved WASH are clear,[31–35] our research shows that the choices individuals make in utilizing and investing in WASH are dictated by higher-level factors. Programs seeking to change health behaviors and, ultimately, reduce disease risk, cannot ignore the broader structures that individuals operate within.[28,111]

Interventions that aim to address individual preferences may be more successful in disrupting WASH choice constraints, preventing the need for water stacking, and ultimately enabling more health-positive behaviors. For instance, more interventions could aim to provide WASH solutions that reduce the time and labor needed to obtain water for chores, which our research indicates are important drivers of WASH choice for mothers. Water for chores is central to sanitation, household cleaning, and personal hygiene activities, all of which translate to indirect health benefits even if the water itself is contaminated. Given increasing global water and energy shortages, countries are increasingly incorporating water sustainability measures that include recycling and treating wastewater and grey water (water used in sinks and showers).[112] Frameworks taking a social justice oriented approach to understanding water-related health inequities, such as the Drinking Water Disparities Framework developed by Balazs and Ray,[53] could be adapted to low-resource settings to highlight water-related disparities in labor and financial burdens. These data could be used to advocate for expanded access to recycled grey water that could be used for chores.

CONCLUSION

Mothers, as individuals, operate at the terminus of the socioecological framework, and their ability to make decisions related to their health and wellbeing is directly impacted by each of the outer layers. In this study we demonstrate that individuals, and particularly mothers, behave in response to constraints that are typically operating at levels outside their control.[113] Women tend to responsible for making WASH-related decisions at the household level,[30] while

men are more likely to lead infrastructure projects and administer urban water and sanitation systems, ultimately dictating the broader structures of access.[114]

This disparity has important implications for the limitations placed on women in the WASH process, where they are so often asked to make tradeoffs between costs, labor, and health,[30] and their relative inability to alter the broader structural factors at play. If individual preference is rarely considered in designing WASH interventions,[16] maternal power and needs may be even less so.[27,28,115] Current efforts need to do more to center the women who bear the brunt of the burden for accessing WASH. A recent review of women's engagement in WASH interventions found that all interventions included were either gender unequal or unaware,[27] meaning that they ultimately did not address the burden on women in providing WASH access for their families.

By listening to individuals and prioritizing the voices and needs of women and the poorest, who currently bear the majority of the WASH burden, the WASH sector may be able to make important progress on equality across urban-rural gradients. Government financing for WASH and other intersectional areas, such as housing, electricity, and poverty alleviation more broadly, is ultimately essential to improve health and wellbeing. By broadening the focus of WASH interventions to consider all the indirect benefits that access can provide, in addition to direct health benefits, the overall impact of such projects could be greatly increased.

Strengths and Limitations

There are many limitations to being an "outsider" conducting qualitative research, but we made conscious efforts to mitigate bias that might arise from such a position. The research collaboration between the Ecuadorian site investigators and other project investigators has a history of more than 20 years, and the field team has supported several grant projects implemented in the same project area over a long span, and has trained personnel and served as a source of continual employment for people living in the region for two decades. As such, our research benefits from the expertise of community members and local scientific experts, and field team members accompanied interviewers or conducted interviews themselves, building on their established multi-year relationships with the ECoMiD study mothers. Although the authors were not able to visit the urban site of Esmeraldas during this research period due to instability in the area, the field workers who did the interviews were local residents. This provided an opportunity to build additional qualitative capacity with our field team.

Mothers might see interviews around WASH products as an opportunity to advocate for themselves, but an advocacy-based perspective would be a welcome one, given the focus of our research question on understanding WASH priorities and needs. The freelist questions related to objects important for various WASH-related activities were asked at the beginning of the interviews, to avoid introducing bias related to what we expected to hear. WASH priorities were limited in part to an extensive preselected list (that could be added to), and were also influenced by the prior content of the discussion, which may have introduced bias. Ultimately the frequency list for WASH priorities incorporated both selections from the list and mentions in open-ended questions together, to provide an overall summary of opinions.

Although transcripts were coded by a single coder, the initial codebook and themes were shared with research team members and field team members before finalizing. Our interview sample was purposive rather than random, and we were able to create targeted strata using

prior study data and relying on team familiarity in the study site. While we sought to include a diversity of wealth levels, the mothers in the study region tend to be poorer compared to other areas nationally. Finally, although the ECoMiD study has generally recruited a complete or representative sample of mothers in most sites, in Esmeraldas we have been unable to sample the entire population due to safety concerns, which may introduce bias.

Future directions

Given the importance of wealth in the process of prioritization and purchasing of WASH products and hardware, a quantitative assessment could complement this qualitative work, to assess the direct effect of socioeconomic status on household WASH and explore the various pathways through which this effect operates. Further, given the numerous barriers to effective household-level WASH solutions, and the maternal preference for clean, consistent, piped water in the home, examining the relative impact of household WASH compared to community WASH infrastructure on child health outcomes, and assessing the ways each are impacted by socioeconomic status, could inform future intervention targeting. Further research on the relative health impacts of mitigating contamination in drinking water compared to improving access to water for chores could also illuminate priority investment areas for WASH. Given that the province of Esmeraldas is likely to continue to experience extreme weather events, further information on the seasonality of infections in the region, and how seasonal patterns, behaviors, and preferences may be differentially mediated by wealth, could also inform the development of climate-suitable WASH interventions.

TABLES AND FIGURES

Table 1: Interview participant characteristics. Demographic information on the mothers participating in the interviews presented overall and by location of the household along the urban-rural gradient, including Esmeraldas (urban site), Borbón (intermediate site), rural sites accessible by road (rural – road), and rural sites accessible only by river (rural – river).

	Overall (N=33)	Urban (N=8)	Intermediate (N=9)	Rural - road (N=8)	Rural - river (N=8)
Wealth tertile (asset-based)					
1 Poorest	8 (24.2%)	1 (12.5%)	3 (33.3%)	3 (37.5%)	1 (12.5%)
2 Middle	15 (45.5%)	6 (75.0%)	4 (44.4%)	1 (12.5%)	4 (50.0%)
3 Wealthiest	10 (30.3%)	1 (12.5%)	2 (22.2%)	4 (50.0%)	3 (37.5%)
Mother's age					
Mean (SD)	27 (6)	28 (7)	22 (3)	26 (5)	32 (6)
Maximum education level					
Primary or less	4 (12.1%)	0 (0%)	0 (0%)	2 (25.0%)	2 (25.0%)
Lower secondary	5 (15.2%)	0 (0%)	1 (11.1%)	0 (0%)	4 (50.0%)
Upper secondary	17 (51.5%)	6 (75.0%)	4 (44.4%)	6 (75.0%)	1 (12.5%)
Post-secondary or greater	7 (21.2%)	2 (25.0%)	4 (44.4%)	0 (0%)	1 (12.5%)
Post-secondary or greater	7 (21.2%)	2 (25.0%)	4 (44.4%)	0 (0%)	1 (12.5%)
Main source water consumption					
Bottled water	12 (36.4%)	1 (12.5%)	6 (66.7%)	4 (50.0%)	1 (12.5%)
Piped water connection	9 (27.3%)	4 (50.0%)	1 (11.1%)	4 (50.0%)	0 (0%)
Rain water	7 (21.2%)	0 (0%)	0 (0%)	0 (0%)	7 (87.5%)
Surface water - river	1 (3.0%)	0 (0%)	1 (11.1%)	0 (0%)	0 (0%)
Tube well	1 (3.0%)	0 (0%)	1 (11.1%)	0 (0%)	0 (0%)
None	1 (3.0%)	1 (12.5%)	0 (0%)	0 (0%)	0 (0%)
Public tap	2 (6.1%)	2 (25.0%)	0 (0%)	0 (0%)	0 (0%)
Piped connection to house					
Yes	15 (45.5%)	6 (75.0%)	3 (33.3%)	6 (75.0%)	0 (0%)

	Overall (N=33)	Urban (N=8)	Intermediate (N=9)	Rural - road (N=8)	Rural - river (N=8)
Type of bathroom					
Toilet - sewer	10 (30.3%)	8 (100%)	1 (11.1%)	1 (12.5%)	0 (0%)
Toilet - septic	11 (33.3%)	0 (0%)	0 (0%)	7 (87.5%)	4 (50.0%)
Toilet - pit	6 (18.2%)	0 (0%)	4 (44.4%)	0 (0%)	2 (25.0%)
Toilet - other place	1 (3.0%)	0 (0%)	0 (0%)	0 (0%)	1 (12.5%)
Pit latrine with slab	2 (6.1%)	0 (0%)	2 (22.2%)	0 (0%)	0 (0%)
Pit latrine without slab	2 (6.1%)	0 (0%)	1 (11.1%)	0 (0%)	1 (12.5%)
Plastic bucket	1 (3.0%)	0 (0%)	1 (11.1%)	0 (0%)	0 (0%)
Share bathroom					
Yes	2 (6.1%)	0 (0%)	1 (11.1%)	0 (0%)	1 (12.5%)

Table 2. Frequency of WASH-related freelist and priority responses by site. Results are shown beneath each WASH topic. The three freelists are in response to the prompt "please list, in any order, the things you and your family need to…": **2a** get the drinking water you need; **2b** get the water for chores; **2c** keep your house clean and hygienic; **2d** prioritize to add to the home related to WASH. WASH priorities were determined by selection from a pre-set list or direct mention during open-ended interviews. Blue shading highlights the frequency of responses, with darker blue indicating higher frequencies either overall or separately by location of the household along the urban-rural gradient, categorized as urban, intermediate, rural – road accessible or rural – river accessible.

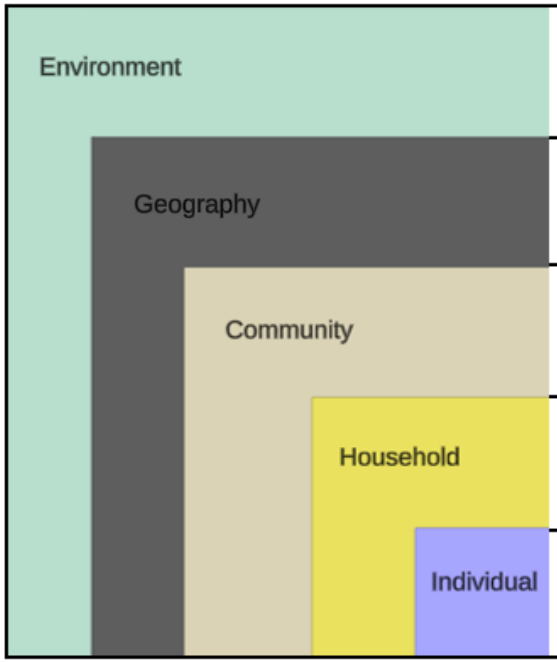
Items listed	Freq	Rel. Freq	Freq	Rel. Freq	Freq	Rel. Freq	Freq	Rel. Freq	Freq	Rel. Freq
2a: Things you need to get the **drinking water** you need for you and your family										
	Overall		Urban		Intermediate		Rural Road		Rural River	
Purchased water	23	70%	4	50%	8	89%	6	75%	5	63%
Rain water	12	36%	0	0%	3	33%	2	25%	7	88%
Piped water	9	27%	5	63%	1	11%	3	38%	0	0%
Water tank	8	24%	4	50%	1	11%	1	13%	2	25%
Water drum	7	21%	2	25%	1	11%	0	0%	4	50%
Chlorine treatment	4	12%	1	13%	0	0%	0	0%	3	38%
Cistern	2	6%	2	25%	0	0%	0	0%	0	0%
Well	2	6%	0	0%	1	11%	1	13%	0	0%
Gutters	1	3%	0	0%	0	0%	0	0%	1	13%
Waterfall	1	3%	0	0%	0	0%	0	0%	1	13%
River	1	3%	0	0%	0	0%	0	0%	1	13%
Large water drum	1	3%	1	13%	0	0%	0	0%	0	0%
Bucket	1	3%	0	0%	0	0%	0	0%	1	13%

2b: Things you need to get the **water for chores** you need for you and your family										
	Overall		Urban		Intermediate		Rural Road		Rural River	
Rain water	16	49%	1	13%	7	78%	3	38%	5	63%
River water	13	39%	2	25%	2	22%	1	13%	8	100%
Piped water	12	36%	3	38%	2	22%	7	88%	0	0%
Water drum	11	33%	2	25%	5	56%	1	13%	3	38%
Water tank	11	33%	5	63%	4	44%	1	13%	1	13%
Well	6	18%	0	0%	5	56%	1	13%	0	0%
Bucket	4	12%	0	0%	0	0%	1	13%	3	38%
Cistern	3	9%	1	13%	1	11%	1	13%	0	0%
Hose	3	9%	0	0%	2	22%	1	13%	0	0%
Large water drum	3	9%	2	25%	1	11%	0	0%	0	0%
Pump	2	6%	0	0%	1	11%	1	13%	0	0%
Chlorine treatment	2	6%	1	13%	0	0%	0	0%	1	13%
Gutters	1	3%	0	0%	0	0%	1	13%	0	0%
Tubes	1	3%	0	0%	0	0%	1	13%	0	0%
Tap	1	3%	0	0%	0	0%	1	13%	0	0%
Tank truck	1	3%	1	13%	0	0%	0	0%	0	0%

Items listed	Freq	Rel. Freq	Freq	Rel. Freq	Freq	Rel. Freq	Freq	Rel. Freq	Freq	Rel. Freq
2c: Things you need to keep your house **clean and hygienic**, including feces management										
	Overall		Urban		Intermediate		Rural Road		Rural River	
Chlorine treatment	19	58%	3	38%	5	56%	4	50%	7	88%
Disinfectant	12	36%	3	38%	1	11%	3	38%	5	63%
Water	8	24%	5	63%	2	22%	1	13%	0	0%
Soap	8	24%	2	25%	1	11%	3	38%	2	25%
Broom	4	12%	2	25%	1	11%	0	0%	1	13%
Mop	4	12%	2	25%	2	22%	0	0%	0	0%

2d: Priorities to add to your home related to **water or sanitation** (keeping your house clean and hygienic)										
	Overall		Urban		Intermediate		Rural Road		Rural River	
Cistern	20	66%	8	100%	4	44%	4	50%	4	50%
Bathroom	15	45%	1	13%	6	67%	4	50%	4	50%
Piped water	11	33%	2	25%	3	33%	3	38%	3	38%
Shower	7	21%	2	25%	1	11%	1	13%	3	38%
Clean, uncontaminated, or treated water	7	21%	3	38%	2	22%	0	0%	2	25%
Elevated tank	6	18%	1	13%	0	0%	2	25%	3	38%
Pump	6	18%	3	38%	1	11%	1	13%	1	13%
Filter or purifier	4	12%	2	25%	0	0%	1	13%	1	13%
Sewer system	3	9%	1	13%	2	22%	0	0%	0	0%
Tubing	3	9%	1	13%	0	0%	2	25%	0	0%
Permanent or consistent access to water	3	9%	1	13%	2	22%	0	0%	0	0%
Washing machine	2	6%	0	0%	0	0%	2	25%	0	0%
Tap	2	6%	0	0%	0	0%	0	0%	2	25%
Hose	2	6%	0	0%	1	11%	1	13%	0	0%
Well	2	6%	0	0%	0	0%	1	13%	1	13%
Bottled water	2	6%	0	0%	1	11%	1	13%	0	0%
Sufficient water	1	3%	1	13%	0	0%	0	0%	0	0%
Dishwasher	1	3%	0	0%	0	0%	0	0%	1	13%
Counter you can clean	1	3%	1	13%	0	0%	0	0%	0	0%
Cement bathroom floor	1	3%	0	0%	0	0%	1	13%	0	0%
Large water drum	1	3%	0	0%	1	11%	0	0%	0	0%
Big water tank	1	3%	0	0%	0	0%	0	0%	1	13%

Figure 1: Key findings mapped to a socioecological framework. Levels of the socioecological framework are shown on the left, horizontally linked to key themes identified in the interviews. Quotes illustrate each key theme. WASH=Water, Sanitation, & Hygiene.



Both rainy and dry season conditions can worsen WASH access	"It is difficult to fill up your water here because you have to wait for the rain drops to fall and fill up your containers… but you have to do it, that way we save our three dollars, we wash, we do everything." HH 2331 "When the river rises, when it gets out of control it floods, and the water reaches to here, so I imagine a cistern would get clogged and fill with mud." HH 7008
Location on the urban-rural gradient has mixed implications for WASH access	"Here we live in what is called an "invasion" [infomal settlement] and sometimes you have to think about how you are going to manage something… you see that there are no streets here, in other parts [of town] there are, you have to look for a way to manage [to have] a bathroom, and water, we try as much as possible to attain the things that other areas already have." HH 2029
Community infrastructure quality influences maternal WASH preferences and dictates coping behaviors	"Rich families have their cistern in their home because in times when there is no water in the community, they have their security." HH 1149 "The [piped] water isn't treated, it is very dirty, if you drank it I think you would end up with mud in your guts." HH 3117
Reliable, high-quality piped water is the maternal WASH preference at the household level, but WASH prioritization responds to a number of broader constraints	"[When there isn't rain] you have to buy a tank, and here a tank costs three dollars… [it isn't easy] because sometimes you don't have those three dollars… what do we do? We have to wait [to do our chores] until we get the money to pay for it… It's difficult because sometimes there is no water when you need it, and you have to take a loan to buy the water, and that's quite hard, because in one way or another you have to go into debt to get water." HH 2031
Individuals prioritize time-savings associated with WASH access	"It's hard for me, because sometimes I urgently need water and I am home alone with the baby… I have to leave the door shut tight and go quickly to the river and bring up the water I need for cooking… in the summer it is more difficult because the river is further away." HH 4014 "A washing machine is important because right now to wash my clothes I have to leave the girls alone and go down and wash at the well, but when my water tank is full I can wash here." HH 2029

Figure 2: Types of household water storage containers or water access points frequently utilized in households in the study region. All photos taken by the authors.

Figure 3: Constraints to maternal water choice, mapped to a socioecological framework. Constraints shown for the most commonly mentioned water sources or storage containers. Shading matches the socioecological levels indicated in Figure 1: Individual level (purple); household level (yellow), community level (brown), environment level (green).

	Labor intensive	Expensive	Require storage	Potentially intermittent access	More difficult to obtain in the dry season	Can be contaminated in flood events
Piped water				X		
Cisterns	X	X (installation)	X			X
Rain water	X		X		X	X (stored)
River water	X		X		X	X (stored)
Purchased water		X				

SUPPLEMENTAL TABLES AND FIGURES

Interview Guide

Gracias por su participación en esta actividad. El propósito de este ejercicio es entender más sobre sus opiniones – no hay respuestas correctas, ni incorrectas. Estoy aquí para escuchar y aprender más sobre usted y su familia, y espero poder utilizar lo que aprendo para mejorar proyectos de salud público en comunidades como esta. La entrevista durara más o menos una hora. *[Hacer el proceso de consentimiento con la forma oficial, pedir permiso para grabar el audio]*

PARTE 1: LOS BIENES/LAS POSESIONES

Empezamos con una actividad en que voy a pedir que usted haga una lista de objetos. Puedes nombrar a todos los objetos que piense usted, sin límites.

- Por favor, dígame cuales son las cosas/bienes/posesiones **materiales** más importantes que tiene su familia/su casa. *[LISTA – por favor, registre las posesiones en el orden mencionado]*
    - *[¿Puede pensar en alguna otra cosa? ¿Mira alrededor de su casa, su patio, hay alguna otra cosa que quiere añadir a la lista? ¿Puede señalar o muéstrame alguna otra costa que debemos incluir en la lista? ¿Puede pensar en alguna otra cosa parecida a XXXX para incluir en la lista?]*
    - ¿Porque eligió estas cosas? ¿Porque son importantes a su familia?
- Imagínese una familia rica en su comunidad. ¿Qué tiene esa familia/casa?
    - *[¿Puede pensar en alguna otra cosa? ¿Que estaría en su casa/hogar? ¿Su patio? ¿Qué comprarían ellos? ¿Qué harían ellos?]*
    - ¿Hay algo que ellos pueden hacer, que usted y su familia no puedan?
- ¿Hay cosas que sienta usted y su familia que no puedan hacer por falta de dinero?
- ¿Hay cosas que son Importantes para usted y su familia en las que no pueden gastar dinero en este momento, pero le gustaría hacer?
    - Por ejemplo, ¿viajar, su salud, educación, actividades culturales, tiempo con la familia?
- Si usted tuviera $1,000 dólares para gastar (para usted/su familia/su casa), ¿cómo lo gastaría? ¿Porque?

Sortea de pilas 1: ¿Cuáles posesiones son las más importantes como señales de la riqueza de una familia? Por favor, ordena/clasifique estas tarjetas en **grupos de lo que tendría una casa de clase alta, una casa de clase media, y una casa de clase baja.** No hay respuestas correctas ni incorrectas, estoy muy interesada en que piensa usted.

Usted puede hacer tantas pilas/categorías/montones como quiera, pero no pueda poner todas las tarjetas juntas en una sola pila/montón. Por ejemplo, ponga cosas que indica/significa que una casa es de clase alta juntos. ¿Cómo sabe que la casa tiene mucho dinero? Si parece que falta unas cosas importantes, podemos añadir tarjetas. *[si la participante ha mencionado unas cosas nuevas en la actividad de lista, añade tarjetas con estas cosas al sorteo].*

Tarjetas:

Un Radio	Un Reproductor de DVD
Un Teléfono no móvil	Un Solar
Una Microonda	Una Motosierra
Un Televisor	Un Motor
Un Refrigerador/nevera	Una Cuenta bancaria
Una Computadora	Una Lavadora
Un Reloj de pulsera	Aire acondicionado
El Internet	Una ducha
Un Teléfono móvil	Un calientaplatos
Una Bicicleta	Una plancha
Una Motocicleta	Un horno
Una Pasola/Scooter	Un ventilador
Un Carro tirado por animales	Una cámara de video/videocámara
Un Coche o un camión	Un aparato de ejercicio
Un Barco con un motor	Una sandwichera
Una Licuadora	Una batidora eléctrica
Una Estufa de gas	Una casa (dueño)
Una Machina de coser	La electricidad / la energía
Un Estereo	Piso de cemento
Una Canoa	Ganado/animales de la hacienda
Paredes de cemento	
Techo de metal	
Techo tejada	

- ¿Es importante el número total de las cosas que tiene la familia? ¿Para cuales posesiones?
- ¿Si solo podría elegir **dos** de las tarjetas para representar cada grupo, cuáles serían?
- ¿Cuáles posesiones son lo más importantes a tener en su casa, específicamente, en su opinión? ¿Porque?
- Por favor, describe la casa de clase alta ¿Qué cosas usted ha incluido? ¿Porque? ¿Cuáles son los más importantes?

- Por favor, describe la casa de clase medio. ¿Qué cosas usted ha incluido? ¿Porque? ¿Cuáles son los más importantes?
- Por favor, describe la casa de clase baja. ¿Qué cosas usted ha incluido? ¿Porque? ¿Cuáles son los más importantes?

[Después de completar la actividad, registra el "nombre" de cada pila y los números de las tarjetas en la pila]

PART 2: WASH

En esta parte de la conversación, quiero aprender más sobre como utilizan varias cosas en su casa y en su vida diaria y cuales cosas son lo más importantes. En particular, estoy interesada en cómo la gente en su comunidad y usted obtengan agua para beber, como obtengan agua para uso en la casa/para oficios, y como mantienen una casa limpia e higiénica, incluso de como manejan las heces de la familia/sus animales. Primero voy a pedir que haga tres listas de objetos. Son todos parecidos, pero cada lista tiene un enfoque/tema un poco diferente.

- Por favor, dígame cuales son las cosas más importantes que tiene su familia/una casa en su comunidad para tener el agua para consumo/para beber que necesitan. *[LISTA – por favor, registre las posesiones en el orden mencionado]*
    - *[¿Puede pensar en alguna otra cosa que utilizan? ¿Puede mirar en su cocina, su baño, o su patio, y pensar en que tipos de objetos utilizan allí? ¿Puede pensar en alguna cosa parecida a XXXX para incluir en la lista?]*
    - ¿Me puede explicar porque has pensado en estas cosas?
    - ¿Hay algunos en la lista que usted no tenga? ¿Porque no ha comprado o construido XXX cosa?
    - ¿Las cosas importantes cambian entre la temporada de lluvia y estación seca, con inundaciones, o con sequias?
- Por favor, dígame cuales son las cosas más importantes que tiene su familia/ una casa en su comunidad para tener el agua domestica/para oficios que necesitan. *[LISTA – por favor, registre las posesiones en el orden mencionado]*
    - *[¿Puede mirar en su cocina, su baño, o su patio, y pensar en que tipos de objetos utilizan allí? ¿Puede pensar en alguna cosa parecida a XXXX para incluir en la lista?]*
    - ¿Me puede explicar porque has pensado en estas cosas?
    - ¿Hay algunos en la lista que usted no tenga? ¿Porque no ha comprado o construido XXX cosa?
    - ¿Las cosas importantes cambian entre la temporada de lluvia y estación seca, con inundaciones, o con sequias?
- Por favor, dígame cuales son las cosas más importantes que tiene su familia/ una casa en su comunidad para mantener una casa limpia e higiénica - incluso el manejo de las heces de las personas, los niños, y los animales. *[LISTA – por favor, registre las posesiones en el orden mencionado]*
    - *[¿Puede pensar en alguna otra cosa que utilizan? ¿Puede mirar en su cocina, su baño, o su patio, y pensar en que tipos de objetos utilizan allí? ¿Puede pensar en alguna cosa parecida a XXXX para incluir en la lista?]*
    - ¿Me puede explicar porque has pensado en estas cosas?
    - ¿Hay algunos en la lista que usted no tenga? ¿Porque no ha comprado o construido XXX cosa?
    - ¿Las cosas importantes cambian entre la temporada de lluvia y estación seca, con inundaciones, o con sequias?
- Imagínese una familia rica en su comunidad. ¿Qué tiene esa familia?

- ¿Que tienen para obtener el agua para consumir que necesitan? ¿Hay diferencias para ellos entre la temporada de lluvia y estación seca, con inundaciones, o con sequias?
- ¿Que tienen para mantener una casa limpia e higiénica? - Incluso el manejo de las heces de las personas, los niños, y los animales.
- ¿Cuáles son las diferencias más importantes entre como una casa de clase alta y uno de clase baja manejan estas cosas?

Sortea de pilas 2: **Por favor, ordenar estas tarjetas en el orden de la prioridad de tenerles en su casa para ayudarle tener agua suficiente a beber, para sus tareas/oficios, y para mantener una casa limpia/higiénica, si podría añadirles horita sin costo.** ¿Por ejemplo, si usted podría añadirles, construirles, o tenerles en su casa, cuales quería poner primero? Si parece que falta unas cosas importantes, podemos añadir tarjetas.
ALTERNATIVA: Pregunta abierta: **Cuales cosas usted considera prioridades a poner en su casa para ayudarle tener agua suficiente a beber, para sus tareas/oficios, y para mantener una casa limpia/higiénica, ¿si podría añadirles horita sin costo?** ¿Por ejemplo, si usted podría añadirles, construirles, o tenerles en su casa ahora, cuales quería poner primero?

- ¿Si usted tenía acceso consistente a agua de grifa, hay otras cosas que serían prioridades? ¿Cuales? ¿Porque?
- ¿Hay cosas en las tarjetas que quieres tener? ¿Porque?
  - ¿Que no quieres tener por razón de la falta de agua?
- Cuales cosas son las más caras/ difícil obtener? Y los más baratos/fáciles de obtener?

Tarjetas:

Pozo con tubería/protegido	Motobomba
Manantial protegido	Agua guardada y cubierto
Agua superficial - río	Cisterna
Agua potable	Pomas
Grifo público	Tanque /tambor
Carro-tanque pequeño/tambor o Camión cisterna	Agua tratado con cloro
Agua lluvia	Agua tratado con abate/abate
Agua embotellada	Filtro de agua
Acceso a agua dentro del hogar	Inodoro que descarga al sistema de alcantarillado o tanque séptico
Acceso a agua de un vecino	Letrina de pozo mejorada y ventilada
Un Fregadero/Lavamanos	Panales
Agua de buen color	Piso del baño de cemento

Agua de buen sabor	La letrina o inodoro adentro de la casa
Acceso consistente al agua	Acceso a una letrina o un inodoro no compartida
Agua sin contaminación	Acceso a una letrina o un inodoro de un vecino
Una lavadora	Jabón en la casa
Una fregona/escoba	Ducha en la casa
Un mostrador de cocina que puede limpiar	Una refrigeradora/nevera

- ¿Si usted tenía acceso consistente a agua de grifa, hay otras cosas que serían prioridades? ¿Cuales? ¿Por qué?
- ¿Hay cosas en las tarjetas que no quieres tener? ¿Por qué?
    - ¿Que no quieres tener por razón de la falta de agua?
- ¿Porque son tan importantes las cosas que son sus prioridades? ¿Que facilitan? ¿Sin estos, que no puede hacer?
- ¿Por qué no es importante tener XXX (ejemplo de una cosa no elegida como prioridad)? ¿Si ninguna de esas cosas es importante a tener, cuales cosas serían importantes?
- ¿Hay algunas cosas que no funcionan o no valen la pena tener si no tienen otra cosa para facilitar su uso?
- ¿Cuáles cosas usted quiere tener en su propia casa? ¿Hay otras cosas no en las tarjetas que le gustaría tener en la casa?
- Cuales cosas son las más caras/ difícil obtener? Y los más baratos/fáciles de obtener?
- Cuáles serían las diferencias más significantes/importantes entre una casa de clase alta y una casa de clase baja, en términos de tener y utilizar estas cosas?

[Después de completar la actividad, registra el "nombre" de cada pila y los números de las tarjetas en la pila]

<u>Preguntas abiertas</u>

- ¿Qué piensa usted es la parte más difícil de manejar/gestionar las necesidades de su y su familia de agua? ¿Qué parte es lo más fácil?
    - ¿Que ayudara a usted a tener el agua que necesita?
    - ¿Hay cosas en que no gasta dinero en este momento, pero que piensa que son importante para sus necesidades y compraría si podría?
    - ¿Cuáles cosas relacionadas al agua son compras diarias y cuales son compras más grandes/para largo plazo?
    - ¿Cuáles cosas puede construir que facilitaran el proceso?
    - ¿Cuáles actividades ayuda con este proceso/son necesarios que haga? ¿Cuáles oficios están relacionados?
- ¿Qué piensa usted es la parte más difícil de manejar/gestionar las necesidades de su y su familia de mantener la casa higiénica, incluso el manejo de heces? ¿Qué parte es lo más fácil?
    - ¿Qué tipo de inodoro tiene? ¿Dónde dispone de los contenidos? ¿Hay un sistema en la comunidad para tratar los desechos? ¿Cómo funciona cuando no hay agua?
    - ¿Que ayudara a usted a mantener una casa limpia, incluso el manejo de heces?

    - ¿Hay cosas en que no gasta dinero en este momento, pero que piensa que son importante para sus necesidades y compraría si podría?
    - ¿Cuáles cosas relacionadas al manejo de heces son compras diarias y cuales son compras más grandes/para largo plazo?
    - ¿Cuáles cosas puede construir que facilitaran el proceso?
    - ¿Cuáles actividades ayuda con este proceso/son necesarios que haga? ¿Cuáles oficios están relacionados?
- Si usted tuviera $1,000 dólares para gastar (para usted/su familia/casa) pero solo podría gastarlo en cosas que facilitan el proceso de obtener agua potable/de consumo, agua doméstica, en la maneja los desechos, y el mantenimiento de una casa/familia higiénica, ¿cómo lo gastaría? ¿Por qué?
- ¿Para comprar o construir una cisterna o un baño/inodoro nuevo, cuánto dinero necesitara tener disponible? ¿Porque o porque no quiere comprar o construir ese tipo de cosas?
- Siente que la comunidad o el lugar en que usted y su familia viven haga una diferencia en su habilidad de obtener agua potable/de consumo o agua doméstica o mantener de una casa higiénica, incluso el manejo de heces?
    - ¿Tiene un sistema alcantarillado en su comunidad? ¿Cómo funciona?
    - ¿Cómo si o cómo no? ¿Es más fácil o más difícil para madres en otras comunidades para obtener esas cosas? ¿Por qué?
    - ¿Qué le gustaría tener en su comunidad que no tiene ahora?
    - ¿Qué tiene una comunidad “ideal”?
- ¿Qué hace usted para evitar tener diarrea/evitar que sus niños y su familia tienen diarrea?
    - ¿Depende en cosas que puede comprar, o cuánto dinero tiene, o dónde vives?
    - ¿Algunas de las cosas de las actividades de los dos sorteos son importantes?
    - ¿Qué hacen madres en otras comunidades para evitar tener diarrea?
- ¿Qué hace usted para evitar el dengue/evitar que sus niños y su familia contagie del dengue?
    - ¿Depende en cosas que puede comprar, o cuánto dinero tiene, o dónde vives?
    - ¿Algunas de las cosas de las actividades de los dos sorteos son importantes?
    - ¿Qué hacen madres en otras comunidades para evitar tener el dengue?

Original, untranslated versions of quotes included in this manuscript, in order of mention

A veces en la ciudad si, a veces uno se queda sin agua hasta los tres, cuatro días, pero acá por lo menos que del río la tenemos todo, todo el tiempo. **HH 7010**

Pues no sé cómo le llamaría pero que el agua saliera más limpia, porque a veces el agua sale como, como café como, como agua del río, del río y sale sucia. **HH 2125**

Una agua limpia que uno salga y abra la manguera y se vea una agua limpia que no hay que guardar, ja, ja, ja, ja…..eso…eso sirve para el baño y uno quiere agua para beber, no, ji, ji, ji. **HH 3117**

Cuando llueve duro hay gente que recoge su agua de lluvia ya pues cuando no llueve mandan el agua potable, solo que esté dañado no mandan, ahí si está dañado uno va al río agarrar su agua o sino uno pide y va a cargar allá en el agua potable, aja, eso. **HH 3207**

Bueno para conseguir agua cuando llueve… se recoge el agua de lluvia ya, y cuando ya entonces se recoge el agua de lluvia hay tiempos que la lluvia no, no está lloviendo entonces a veces nos toca agarrar del río y poner a hervir o sino pues si se tiene comprar su botellón de agua le manda a comprar. **HH 7008**

La diferencia que la de allá es más tratada y la de acá es como que bueno en término de que a nosotros nos toca que nos, o sea la clase media o baja nos toca por ejemplo ya comprar una agua como para estar tomando y ellos utilizan la misma agua para todo porque el agua de ellos es más tratada, la de nosotros bueno si hablamos en términos de grifo la llave ya es cosa que no es tan, no, no, no utilizamos como para cocinar, para poder no, o sea ya tenemos una agua específica como para poder cocinar y otra como para hacer oficio o hacer la limpieza acá. **HH 2414**

Uno con la cisterna uno la llena si no hay agua ya tiene de a dónde sacar su agua no le hace falta. **HH 3207**

Realmente tendríamos que nosotros mismo tratarla he, ya ponerle su abate y estarlo he, por ejemplo limpiando consecutivamente porque también a veces viene de que cuando se pone la cisterna también viene de que adentro se, el agua como que se, se ha juntado algo así ya… Incluso hasta cucarachas se le meten ahí… Sapos… y a veces uno no se da cuenta y el agua está corriendo por toda la casa y uno piensa que el agua está siendo bien tratada y no es así, si, son he, siempre para uno mantener un tanque o algo tiene que estarlo revisando continuamente, lavando continuamente si para que pueda tener seguridad por su agua. **HH 2414**

Mejor sería que venga directamente el agua de la llave y no tener como cuando hay la cisterna porque hay veces que el agua de la cisterna pasa mucho tiempo y como que se abomba así entonces también hay que estarla limpiando, eso mantenerlo limpio también no es, no es bueno que el agua está así, mejor sería directamente el agua a la llave no ver la cisterna por allá. **HH 2125**

Aquí porque no es mi casa. **HH 3207**

Porque no hay un lugar adecuado donde se la pueda hacer, no hay un lugar adecuado. **HH 4012**

Porque el terreno no se presta para estar haciendo excavaciones para hacer porque abajo es pura peña, peña fina que no puede que el hacha rebota aja. **HH 4014**

Por ejemplo lo más barato como quién dice para he, talvez barato en corto plazo pero a largo plazo es costoso el bidón de agua porque por ejemplo usted puede talvez, porque a mí me dejan por mes, porque se me hace más fácil porque toca comprar todos los días, ha, entonces al mes me deja el señor entonces es mensualmente uno cobra y paga como a, por eso le vuelvo y le repito a corto plazo es económico pero a largo plazo es costoso porque si nos ponemos a calcular al año cuánto uno se gasta, pero es lo más accesible creo que es el bidón de agua, aja. **HH 3124**

Mire pue, ellos allá tienen más, más posibilidades de agua y todo acá uno no tiene, ellos allá tienen todo ya, y acá uno tiene que comprar y buscar todos los día, allá no, ellos allá no compran todos los días y lo que pagan es mensual mientras acá nos toca pagar todos los días, cuando se acaba el tanque de agua uno tiene que comprar. **HH 2237**

Ha, si tuviera si, ja, ja, si….como no querer. **HH 2031**

Porque uno de allá tiene que subir la poma y uno se cansa, a veces no llueve y no hay dinero para comprar los bidones, y es duro. **HH 11**

Difícil, difícil si porque se seca el, y si los que tienen su agua van a llenar tenemos que hacer llenar, llénname un tanque de agua y lo cobran a dólar y medio el tanque cuando no llueve, pero cuando llueve yo hay si con mi pierna así salgo allá afuera trato de llenar los tanque que tengo allá a las poma, los tacho, los balde, pero cuando no llueve entonces los que llenan con bomba a uno le, cada uno un tanque dólar y medio. **HH 7008**

Es que para tener la casa limpia y aseada tiene que haber es agua y yo no veo cuál es la diferencia si no hay, si no tiene agua pues por más que barra y si no puede asear el baño cómo hacemos. **HH 1046**

He, lo primordial sería el agua…..este, también uno tiene su desinfectante para limpiar el piso, he, tiene para mantener limpia las sillas todo para que esté todo desinfectado pero lo primordial para tener todo limpio es el agua. **HH 1149**

Socioecological model quotes, listed from environment to individual

Difícil llenar agua porque hay que estar llena esperar que la gotera caiga y llene el envase para traspasar difícil…….llenar pomas, pero hay que hacerlo pues si ahí nos ahorramos los tres dólar que uno se ahorra, uno lava uno todo hace. **HH 2331**

Cuando se crece el río, que los río salen fuera de control se hunde pues, esto llega el agua hasta aquí entonces me imagino que se tapa y se llena de lodo. **HH 7008**

Esto es una invasión y uno a veces tiene que coger y pensar de qué manera lo hace, cómo lo hace porque igual esto no es de uno ya pero uno igual por su comodidad uno lo hace, lo trata de, de hacerlo, pero si diferencia igual si hay usted ve aquí calles no hay, en otras partes en, en otras partes si hay, hay uno se rebusca con lo que es el baño, con lo que es el agua nos rebuscamos tratamos pues en lo más posible de conseguir unas cosas que en otras partes si hay. **HH 2029**

Las familias ricas ellos…….ellos tienen su cisterna, su, su algiber en su hogar porque digamos en el tiempo de que no hay agua en la comunidad ellos tienen su respaldo porque tienen su algiber seguro. **HH 1149**

El agua pues yo no sé qué traten mejor está muy sucia huuu esa agua huuuu como para beber creo que le queda todo mugre en las tripa, ja, ja, ja, ja… **HH 3117**

Se compra el tanque de, aquí un tanque así cuesta tres dólar…. a veces no hay esos tres dólare … Que le hacemos …..nos aguantamos hasta que consigamos para pagarlo ya… Es difícil porque a veces no, no hay agua cuando uno necesita y hay que estar prestándola así para poder comprar el agua….aja, y ante eso es bastante duro porque de una u otra forma tiene que endeudarse en plata para el agua. **HH 2031**

Para mí es difícil porque a veces necesito de urgente y me quedo más con la bebe… tengo que dejar la puerta un poco ajustada ir rápido al río y subir porque ya para atender la bebe agarra el agua lo que voy a utilizar en la cocina y lo que voy a echar en el tacho del baño, ya. **HH 4014**

Lavadora también es importante porque igual aquí para yo poder lavar yo tengo que dejarlas a ellas sola y me bajo al pozo, lavo ahí en el pozo, cuando lleno el tanque me pongo a lavar aquí. **HH2029**

Supplemental Table 1: Sampling frame for qualitative interviews. Purposive sample of 33 households selected from the 521 households participating in the ECoMiD study, stratified by socioeconomic status and by location of the household on the urban-rural gradient, including Esmeraldas (urban site), Borbón (intermediate site), rural sites accessible by road (rural – road), and rural sites accessible only by river (rural – river), to ensure a variety of contexts were represented.

	Urban *Actual N* *(target n)*	Intermediate *Actual N* *(target n)*	Rural – road *Actual N* *(target n)*	Rural – river *Actual N* *(target n)*	Totals *Actual N* *(target n)*
Low SES	4 (3)	3 (3)	2 (3)	3 (3)	**12 (12)**
Mid SES	1 (2)	3 (2)	3 (2)	3 (2)	**10 (8)**
High SES	3 (3)	3 (3)	3 (3)	2 (3)	**11 (12)**
Totals	**8 (8)**	**9 (8)**	**8 (8)**	**8 (8)**	**33 (32)**

**SES = socioeconomic statues*
Ad-hoc SES score developed using ECoMiD study data on asset ownership

Supplemental Table 2: Data Overview for In-Depth Interviews. Household ID, date of interview, location of interview, person conducting interview, transcriber, language of interview, and length of interview provided for all interviews conducted as a part of this study.

Study ID	Interview Date	Site	Interviewer	Transcriptionist	Language	Length (minutes)
2029	231106	Intermediate	Molly M.P.	Maritza C.L.	Spanish	41’33”
2125	231106	Intermediate	Molly M.P.	Maritza C.L.	Spanish	31’19”
2237	231106	Intermediate	Molly M.P.	Maritza C.L.	Spanish	52’43”
2414	231106	Intermediate	Molly M.P.	Maritza C.L.	Spanish	31’49”
2031	231107	Intermediate	Molly M.P.	Maritza C.L.	Spanish	33’17”
2235	231107	Intermediate	Molly M.P.	Maritza C.L.	Spanish	31’16”
3117	231108	Rural-road	Molly M.P.	Maritza C.L.	Spanish	49’45”
3124	231108	Rural-road	Molly M.P.	Maritza C.L.	Spanish	58’44”
3207	231108	Rural-road	Molly M.P.	Maritza C.L.	Spanish	45’13”
11	231109	Rural-river	Molly M.P.	Maritza C.L.	Spanish	31’9”
4012	231109	Rural-river	Molly M.P.	Maritza C.L.	Spanish	35’49”
7008	231109	Rural-river	Molly M.P.	Maritza C.L.	Spanish	36’49”
7010	231109	Rural-river	Molly M.P.	Maritza C.L.	Spanish	37’54”
4010	231110	Rural-river	Molly M.P.	Maritza C.L.	Spanish	34’
4014	231110	Rural-river	Molly M.P.	Maritza C.L.	Spanish	34’44”
5004	231110	Rural-river	Molly M.P.	Maritza C.L.	Spanish	36’16”
5011	231110	Rural-river	Molly M.P.	Maritza C.L.	Spanish	35’
2331	231113	Intermediate	Molly M.P.	Maritza C.L.	Spanish	36’59”
1304	231114	Intermediate	Molly M.P.	Maritza C.L.	Spanish	32’17”
1346	231114	Intermediate	Molly M.P.	Maritza C.L.	Spanish	32’38”
2334	231114	Rural-road	Molly M.P.	Maritza C.L.	Spanish	38’42”
2461	231114	Rural-road	Molly M.P.	Maritza C.L.	Spanish	33’23”
6014	231115	Rural-road	Molly M.P.	Maritza C.L.	Spanish	32’26”
8014	231115	Rural-road	Molly M.P.	Maritza C.L.	Spanish	29’54”
8027	231115	Rural-road	Molly M.P.	Maritza C.L.	Spanish	27’13”
1046	231122	Urban	Grace M. Q.	Maritza C.L.	Spanish	23’13”
1130	231122	Urban	Grace M. Q.	Maritza C.L.	Spanish	30’43”
1142	231122	Urban	Grace M. Q.	Maritza C.L.	Spanish	38’48”
1146	231122	Urban	Grace M. Q.	Maritza C.L.	Spanish	34’9”
1149	231122	Urban	Diana B.A.	Maritza C.L.	Spanish	38’4”
1216	231123	Urban	Diana B.A.	Maritza C.L.	Spanish	29’39”
1031	231127	Urban	Diana B.A.	Maritza C.L.	Spanish	26’38”
1214	231127	Urban	Diana B.A.	Maritza C.L.	Spanish	25’28”

Supplemental Table 3: Codebook. Codes applied to open-ended interview data in Atlas.ti. Category of the code, any clarifying comments, and inclusion and exclusion criteria for applying the code included as applicable. WASH = Water, Sanitation, and Hygiene.

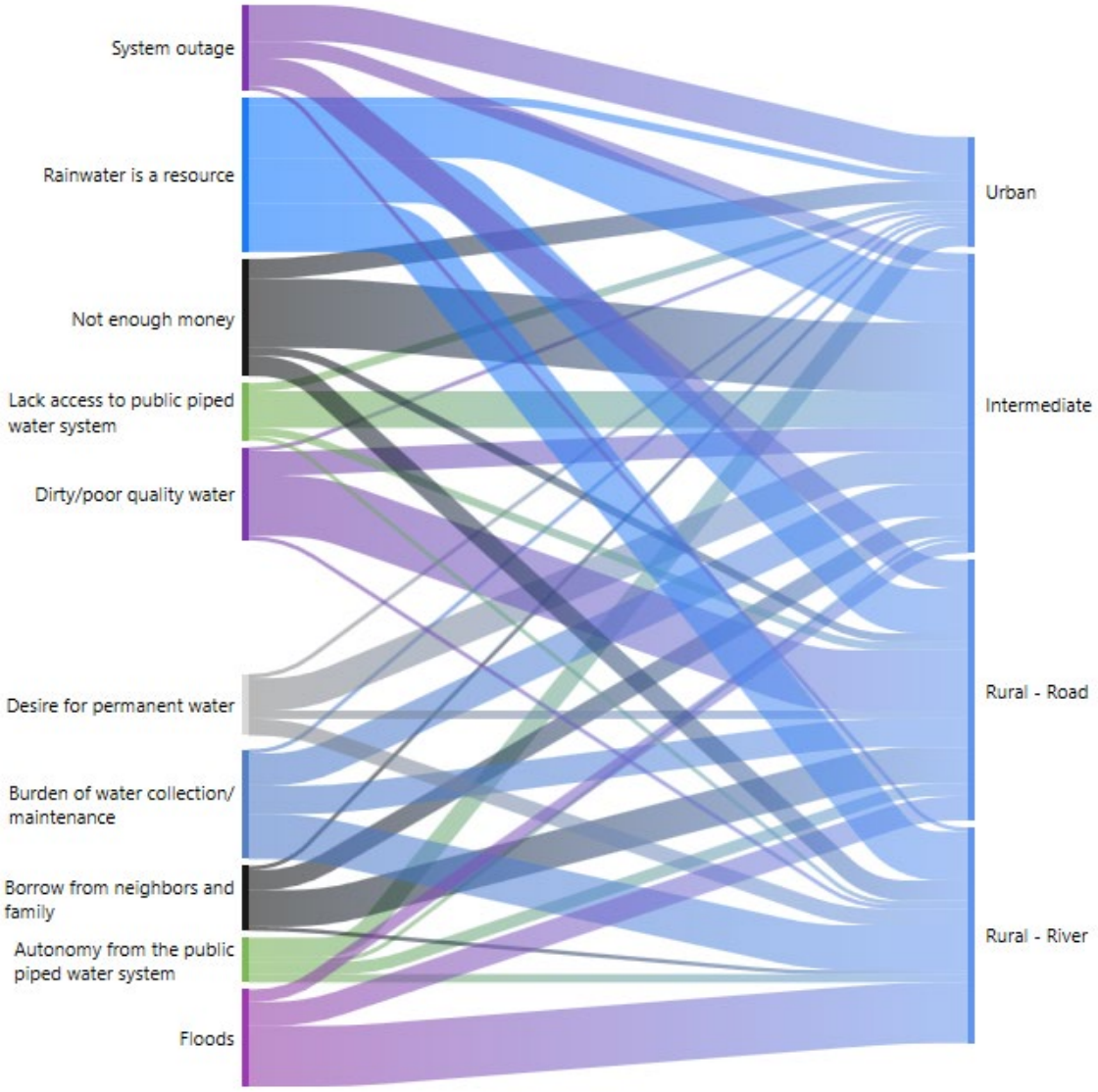
Code	Category	Comment	Inclusion	Exclusion
Autonomy from the public piped water system	Household WASH; solutions	Mother discusses advantages of having WASH resources outside the piped water system	Water system or other WASH resource that is discussed as beneficial because it is not limited by the public community connection (e.g. a cistern, a well)	Discussion of limitations or disadvantages related to not being connected to the public piped water system or other WASH community infrastructure
Borrow from neighbors and family	Solutions	Mother discusses borrowing water, toilet, or other WASH resource from others	Mother discusses borrowing water, toilet, or other WASH resource from others	Mother purchases water or other WASH resource externally
Burden of water collection /maintenance	Challenges	Discussion of physical and temporal difficulties related to collecting water	Includes labor for collection and maintenance, time	Does not include financial burden
Challenges of poverty	Challenges, wealth	Discussion of the challenges of poverty	Related to living day by day, broad statements on struggle related to money, specific challenges	Does not include challenges related specifically to buying water as those are captured elsewhere
Commonalities	Maternal opinions	Discussion that mothers share challenges or lived experiences	Experiences with WASH or children/child health across class divides; communities; among mothers	Only applies to expressed maternal opinion, not perceived commonality by coder
Community WASH factors	Community WASH	Anything related to community level infrastructure or context as related to WASH	Community water systems, community sewer systems, flooding, terrain	Does not include household access to community infrastructure, as that is captured in other codes
Daily purchases	Wealth	Discussion of need to purchase or acquire items every day/most days	Mention of frequent purchasing	Does not include any/all purchases

Differences between communities	Community WASH	Any discussion of differences between study locations	Includes based on geography, economy, culture, etc.	Does not include differences in community WASH infrastructure captured elsewhere
Differences poor vs rich	Wealth	Discussion of any differences between social classes	Discussion of impact of money or SES on any other aspects of life	Does not include mentions of only a challenge of poverty or only a benefit of wealth, must compare groups
Dirty/poor quality water	Challenges, community WASH	Discussion of poor-quality water	Appearance, taste, contamination level, health	Does not include intermittency – see “outage”
Drinking water is expensive	Challenges, wealth	Mother mentions cost of obtaining drinking water	Drinking water costs	Chore or sanitation related water costs
Floods	Challenges, community WASH	Discussion of flooding in the house or community	Any mention of the word flood	NA
Have to save	Challenges, wealth	Discussion of saving up to buy something	Any mention of the word save, process of saving up	NA
HH hardware solution - expensive	Household WASH	Discussion of HH WASH product being expensive	Must discuss how a specific item is expensive	Does not include bottled water/water generally
HH hardware solution - infeasible	Household WASH	Discussion of HH WASH product not being a good fit/difficult to add to the house	Must discuss limitations of a specific item	Does not include unaffordability
HH hardware solution - valuable	Household WASH	Discussion of HH WASH product being valuable as an addition to the house	Must discuss a specific item for HH WASH	Valuable = useful, wanted, appreciated vs. monetary value
Home is in an illegal settlement (“informal settlement”)	Challenges, community WASH	Discussion of living in an illegal settlement (“informal settlement”)	Any mention of house being in an “informal settlement”	NA
Home isn’t owned	Challenges	Home is not owned by the mother	Home is rented, borrowed, belongs to a relative	Home is in an informal settlement
Household WASH factors	Household WASH	Anything related to household context as related to WASH	Broad	Anything discussing community infrastructure, external factors
Knowledge of disease prevention	Maternal opinions	Has specific ideas about how to prevent disease	Diarrhea or dengue; can include incorrect	NA

			statements in terms of disease prevention	
Lack access to public piped water system	Challenges, community WASH	Discussion of disadvantages of not being connected to piped water system	Discussion of limitations or disadvantages related to not being connected to the formal piped water or other WASH community infrastructure	Discussion of benefits of not being connected to public piped system; temporary lack of access via outages
Maternal attitudes and priorities	Maternal opinions	Discusses the importance of maternal attitudes or opinions in how a mother behaves, cares for children, makes a home	Includes assets, purchases, investments	Specific WASH priorities or community improvement priorities
Need a lot of water	Challenges	Volume of water needed discussed	Broad	NA
Need water for everything	Challenges	Number of related things water is needed for discussed	Water used for more than just drinking or just chores	Single use of water discussed
No water/run out of water	Challenges	Mention of not having water available at all	Broad	Not related to lack of piped connection or a system outage specifically
Non-material priorities	Priorities	Discusses priorities other than household assets	Education, health, food, saving, children, starting a business, love	Material objects, houses
Not enough money	Challenges	Discuss not having enough money for something	Specific instance of needing money for a concrete thing or activity and not having it	Does not include broad discussions of challenges of poverty
Purchase water	Household WASH, wealth	Discusses purchasing water	Includes for any use	Does not include specific purchases for children only
Rainwater is a contaminant	Challenges	Rainwater is described negatively	Any limitation of rainwater discussed	Does not include contaminating flood events
Rainwater is a resource	Solutions	Rainwater is discussed as an asset or benefit to the house	Any benefit of rainwater discussed	Not as a resource to be sold
Rainwater is not needed/important	Household WASH	Rainwater is discussed as being of no interest or having no impact on the house	Explicit mention that rain water is not important	NA

Dry season	Challenges	Discussion of dry season/lack of rain	Discussion of any impact that the dry season has on the house, community, or WASH	NA
River is last resort	Challenges	Discuss using river water only if you have to	Discuss using river only if they are out of other options, negatively	General discussion of river water
Sanitation requires water	Household WASH, challenges	Discussion that good sanitation or hygiene is not possible or is limited by absence or lack of water	Discuss using water in any sanitation or hygiene capacity	Discussion of sanitation and hygiene not related to water
System outage	Community WASH, challenges	Discussion of lack of availability of water due to an outage in the community piped system	System outages, power outages, intermittency	Does not include lack of access to the piped system itself
“Tengan todo”	Wealth	“En vivo” code - the rich have everything	Specifically in reference to the rich, upper classes	NA
Violence	Violence	Mention of violence in the community	Any mention of violence, security, instability	NA
WASH priority	Priorities	Item or resource defined as a priority for the mother	Discussion of household WASH priorities	Does not include community priorities
Desire for permanent water	Household WASH	Discusses the desire to have constant access to water in the house, e.g. piped water	May also include discussion of wanting constant access to clean water	Not an explicit discussion of the lack of access
Community priorities	Maternal opinions, priorities	Discussion of priorities for what the municipality should add to the community	Discussion of any community-wide/ oriented priority	Does not include household priorities
Buy water for children	Maternal opinions	Specific discussion of children needing their own source of water	Must be purchased bottled water	Does not include purchasing water without specifying for a child or treating water for a child

Supplemental Figure 1: Sankey diagram of select codes by site on the urban-rural gradient. Study sites were located along an urban-rural gradient, and included Esmeraldas (urban site), Borbón (intermediate site), rural sites accessible by road (rural – road), and rural sites accessible only by river (rural – river). Thicker lines represent greater frequency of code occurrence across all interviews from that site.



Chapter 3: The wealth – WASH pathway: A mixed-methods study on relationships between socioeconomic status and water, sanitation, and hygiene access in northwest Ecuador

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ABSTRACT

Introduction: The path from wealth to water, sanitation, and hygiene (WASH) access is underexplored, in part because measuring socioeconomic status (SES) is methodologically challenging. We explore the SES-WASH pathway using mixed-methods; our results can inform interventions to increase equitable access to WASH.

Methods: We first developed a qualitatively-informed asset-based measure of SES utilizing quantitative data from 521 households participating in the ECoMiD cohort study and qualitative data purposively sampled from 33 participating households. We assessed its contextual appropriateness and adequacy across an urban-rural remoteness gradient. We then applied the SES measure to explore its association with complete household WASH using multivariable logistic regression. Complete WASH was defined as access to at least limited or basic water, sanitation, and hygiene facilities. We also explored potential thresholds of wealth in our data.

Results: Comparing two households differing by one standard deviation in wealth, the wealthier household had 1.7 times (95%CI: 1.4-2.1) the odds of complete household WASH, adjusting for remoteness. Among individual WASH components, wealth was most strongly associated with increased likelihood of having basic or limited sanitation. Complete household WASH coverage increased across wealth tertiles, from 51% in the poorest to 73% in the wealthiest. Households in the top tertile of wealth were more likely to own expensive WASH hardware, less likely to share water or sanitation facilities, and more likely to purchase bottled water. Qualitative results suggested that home ownership, competing priorities, social capital, child needs, and costs inform asset accumulation. Mean SES scores decreased along the urban to rural gradient, from a high of 0.32 in the urban site to -0.31 in the most remote communities.

Discussion: We found that wealth corresponds with increased WASH coverage across a range of geographic conditions and identified patterns suggesting high wealth thresholds for WASH ownership. Individual priorities, social capital, and housing ownership likely modify the wealth-WASH pathway. These findings highlight the critical intersection of wealth and WASH and help explain limitations of existing WASH interventions that do not take poverty into account. Accounting for SES in WASH-health studies and WASH interventions will could help efforts to achieve WASH equity.

INTRODUCTION

Despite clear links between water, sanitation, and hygiene (WASH) and health[31–35] and between socioeconomic status (SES) and health,[116,117] the SES-WASH-health pathway remains under-explored,[118,119] and the SES-WASH pathway in particular is under-defined.[28] Both household financial resources and individual user preferences likely drive purchasing and uptake of WASH interventions, and the lack of consideration of these factors may partially explain the limited impact of recent large-scale WASH interventions on health.[36–39] For example, handwashing education interventions may not be effective if there is no money in the household to buy soap and there are other competing priorities for water use.[120] The identification of specific mechanisms and routes from wealth to WASH access are essential to inform interventions that aim to increase equitable access, and to better understand household utilization of WASH infrastructure, hardware, and products.

Access to public infrastructure is often considered an equalizer of wealth disparities: prior research has found that having public WASH infrastructure and community coverage can alleviate the need for household-level WASH investments.[42,46,118,121] Yet research has also shown that in contexts where public infrastructure cannot meet user needs due to insufficiency, unpredictability, or poor quality, the burden placed on households to cope with water insecurity by, for example, purchasing, storing, or collecting other water sources, is highest on the poorest segment of the population.[102] As such, the wealth-WASH pathway is likely different under different community infrastructure contexts. In addition, individuals who do not own their home may be less likely to invest in household WASH hardware, so WASH-related expenditures at the individual or institutional level vary depending on ownership status or the perceived stability of a household's location in a community (e.g., in informal or formal settlements, in flood prone areas or urban outskirts).[122]

Previous research has suggested that there may be high wealth thresholds required to achieve WASH-related health benefits.[123] Given this, it is also important to explore wealth thresholds in specific components of WASH access and product ownership to understand the reasons behind low coverage rates in the poorest sectors of the population. Individual priorities, geography, infrastructure, and housing ownership may all influence the threshold of wealth for a particular household choosing to invest in WASH, but few studies combine all these streams of information into a single analysis.

One potential reason that prior research has not fully explored the SES-WASH pathway is that the measurement of SES in epidemiological studies is notoriously challenging, particularly in low-resource settings. While most variables utilized in scientific research are subject to some level of measurement error or imprecision, social determinants of health, and in particular SES, can be particularly difficult to measure. SES can be generated in different ways with differential effects over the life-course.[124] For example, in childhood, SES may be derived primarily from parental income, parental education, and living conditions; later in life, individual occupation, wealth transfers, and inheritance may play greater roles. No gold standard indicator exists, and while income, occupation, education, and wealth are among the most commonly used SES variables, there is extensive documentation of their limitations.[116,124–126]

Several of these limitations are particularly important in low-resource settings. For instance, income does not fully capture SES in contexts where households produce their own food or goods for consumption, and response rates tend to be low for income-related survey questions, while occupation may not distinguish well between unemployed and stay at home parents.[127] Education is often used as an SES proxy given that it is widely available, relatively stable, and often upstream from occupation and income.[124] However, the relative benefit of years of education may vary in contexts of high unemployment, or offer differing levels of benefits to an individual depending on sexism, racism, agism, and ableism.[128,129] Composite SES indicators[130]

have been criticized for being difficult to interpret, lacking in consistency when used as exposure variables,[131] and limited in their ability to explore a specific pathway through which SES might operate.[124]

Wealth is often defined as income measured in combination with other household asset ownership and/or housing materials and housing ownership variables,[124,132] but can also be defined purely based on asset ownership.[116] Assets are considered relatively stable measures of SES because they take time to accumulate. They also capture wealth at the household level, rather than the individual level. However, the value of individual assets may vary by time and place. Their stable nature also limits their ability to capture changes in wealth status over short time periods.

Finally, it is generally accepted that any one measure used to capture SES is likely incomplete, acting as a proxy, and subject to residual confounding.[124,125,127,131] The selection of an SES indicator can have direct impacts on human health and wellbeing—for example, different measures will result in different populations being categorized as poor, and ultimately determine who receives the benefits and interventions targeted to serve those populations.[133] The current recommendations in the SES literature are to select an indicator based on the exposure-outcome pathway of interest,[124,127] taking both the research question and underlying theory of change into account, or to use a decision tree to select the specific SES-condition of interest impacting the outcome.[126] It is particularly important to determine the time in the life-course of interest for the SES variable (childhood, professional life) and the level (individual, household, area) of measurement that will be most appropriate, given the exposure or outcome of interest.[124,127]

In this mixed-methods study, we take these recommendations into account to create an SES indicator and apply it to an analysis of the SES-WASH pathway. We first develop an SES indicator, assess its contextual appropriateness using qualitative data from interviews

conducted with study participants, and consider its adequacy compared to other SES proxies for use in a cohort study northwest Ecuador.[55] We then apply the indicator to model the effect of SES on household WASH conditions and explore variation in SES and household WASH access across an urban-rural gradient in northwest Ecuador.

METHODS

Study population

The ECoMiD study is a prospective birth cohort in northwest Ecuador.[55] Mother-child dyads were recruited across an urban-rural gradient made up of an urban site (the city of Esmeraldas, pop ~150,000), an intermediate site (the town of Borbón, pop ~4,500), and several small rural villages; 'rural-road' communities accessible by road (pops. ~400-920) and 'rural-river' communities primarily accessed by river (pops. ~200-700). Location on this urban-rural gradient is referred to in this chapter as an indicator of "remoteness". Details on the study protocol and population are provided elsewhere.[55]

Survey data capture household ownership status (owned, rented, borrowed, inherited), but in practice there are further differentiations that are more locally subjective. Households may be formally established within recognized sections of a community, or may be in informal settlements, locally known as "invasions", that are not recognized by the government and not connected to public services. In addition, the government agency "Ministerio de Desarrollo Urbano y Vivienda" (MIDUVI) builds public housing, locally referred to as MIDUVI houses. In Borbón, an entire neighborhood is classified as MIDUVI.

Mixed-methods study design overview

This study used a multi-stage sequential mixed methods study design (Figure 1). Quantitative survey data were collected from the 521 households enrolled in the ECoMiD study, beginning at ~37 weeks of pregnancy through 2 years of child age. Qualitative data were collected from 33 participating mothers to better understand priorities related to wealth and WASH. During the SES indicator creation stage, we used findings from our qualitative data analysis to inform the creation of an asset-based SES indicator using multiple correspondence analysis (MCA) and compared it to other SES proxies in the survey data (see Supplemental Methods). During the SES indicator application stage, we used the SES indicator to explore

patterns in household WASH access by wealth, and to look for thresholds of wealth in ownership of previously identified priority WASH items.

Quantitative data collection

ECoMiD surveys and spot checks provided data on demographic and household characteristics, including household possessions (self-reported), maternal education (years; self-reported), maternal occupation (self-reported), income (average monthly for the household, self-reported), house building materials (roof, walls, floors; observed). Further details on these variables are provided in the Supplemental Methods.

For all indicators where data was collected at multiple study visits, we prioritized data collected when the child was six-months old to capture household conditions at this early life milestone, when children begin to consume non-breastmilk foods and explore their environment, increasing potential exposure to pathogens in the environment. If data at six months were not available, we used data collected at later study visits through age 24 months. The exception to this process was for household asset possession data, which was collected during the pregnancy visit and only repeated if the household moved during the study period.

Qualitative data collection

Details of the qualitative data collection process, including sampling frame, consent process, interviewer information, data collection, and data analysis processes are described in detail elsewhere.[134] In brief, semi-structured in-depth interviews were conducted by author MKMP or trained fieldworkers in Spanish in the participant's homes in November of 2023. All participants were enrolled in ECoMiD, and fieldworkers for ECoMiD, who are Ecuadorian, accompanied the interviewer. Participants provided written, informed consent to participate, distinct from their consent to participate in the ECoMiD cohort. This included consent to audio recording. The

interview guide (provided in Supplemental Methods) was pilot tested with fieldworkers prior to use, and included the following sections:

Open ended questions: A set of open-ended questions were included to understand mothers' perceptions of wealth and differences between different socioeconomic classes in their communities.

Rankings: Each participant also completed a ranking activity,[76] where they used notecards to categorize a pre-set list of household assets into something anyone, from the poorest household and above, would be able to own; something only a middle-class household or above could own; or something only the wealthiest households could own. Assets included in the exercise were derived from the existing SES module of the ECoMiD survey (Supplemental Table 1).

Freelists: Participants were verbally asked to generate a freelist of the "most important material possessions" that they owned, in any order. In addition, a pre-existing list of WASH improvements (e.g., bathroom in the house, water filter) was presented to participants and they were asked which items, if any, would be a priority to install in their home.

Data analysis: SES indicator creation

Data related to SES were derived from household surveys, including information on asset ownership (self-reported), maternal education (years; self-reported), maternal occupation (self-reported), income (average monthly for the household, self-reported), and building materials (roof, walls, floors; observed). Further details on these variables are provided in the Supplemental Methods and Supplemental Table 1.

We selected asset ownership as the basis of our SES measure, as we hypothesized that wealth would primarily act as a means of procuring WASH solutions and/or accessing community infrastructure, and assets also represent purchased goods. From a life-course

perspective, household assets are a fitting proxy for the child's environment during these early years, as asset data were collected in late pregnancy, though as they are stable measures, they may not reflect the exact level of wealth at the time of the child's birth.

We also considered four alternate SES proxies for our WASH analysis: maternal education, housing materials, average monthly household income, and maternal employment. We decided against the use of each these alternate SES proxies, for different reasons. In a national context of high unemployment, maternal education is not likely to reflect downstream employment or income, and thereby purchasing power, though it may still reflect knowledge and other non-occupational educational benefits. While housing materials are a well validated measure in the region[135] and readily observable, there was very limited variation in housing materials in our dataset. Accurate income data can be difficult to collect and less meaningful for those producing their own products for consumption, which is the case for many of the households in our study area. Further, there is the possibility that respondents underreport income in contexts where government funds are provided to low-income households, such as the Bono de Desarollo Humano[136] conditional cash transfer program in Ecuador. Finally, employment data for mothers in our population is difficult to interpret, as they tend to be the primary caregivers of children. Employment data for the fathers in our study households could provide a more effective proxy, were it available, particularly using an indicator that could distinguish between professional, salaried work and other informal work.

An initial asset-based SES measure was created using MCA[137] – considered a statistically efficient measure –[132,138,139] on binary ownership data for the 15 possessions included in the household survey conducted in late pregnancy. This process was repeated to create a final asset-based SES indicator after inputs to the MCA were refined by dropping four assets that either had low overall prevalence (<5%) in the dataset or were not well understood by mothers in the qualitative data analysis described below.

To assess the overall appropriateness of using an asset-based measure for our study population, open-ended interview data were inductively coded in Atlas.ti [75] by author MKMP, who maintained a codebook, as described previously.[134] We used analytic memos to relate codes and themes to the research questions.[134] Initial results were shared with field team members for feedback. First, to assess if ownership of the assets we had data on was likely to vary across SES strata, we analyzed asset ranking results by the frequency an asset was placed into each of the three SES categories described above. Second, to assess if the assets we had data on were important and relevant to mothers, we analyzed Freelist responses for important possessions by frequency of mention, in any order, as the prompt did not ask the mothers to order by importance. WASH priority data were analyzed alongside open-ended response data to generate a list of top household WASH priorities overall by frequency; these results have been described elsewhere,[134] and were used primarily in the SES indicator application stage to explore thresholds of wealth (Figure 1).

To assess the adequacy of the final asset-based SES indicator across geographic conditions, we compared its functionality in measuring wealth across the four remoteness sites by calculating area under the receiver operating characteristic (ROC) curves with the binary versions of the four other SES proxies in each remoteness site (see Supplemental Methods and Supplemental Table 4).

Finalized SES indicator

Once the SES indicator was finalized, wealth scores were generated for each household by summing the weighted scores for each possession generated from the first dimension of the MCA and dividing the sum by the total number of assets multiplied by the square root of the eigenvalue of the first dimension. We applied the Benzécri correction to the eigenvalues.[140,141] The continuous household wealth score was used to create 1) wealth tertiles and 2) a binary

indicator of a household being above or below mean wealth. When used in statistical analysis, the continuous indicator was scaled to have a mean of zero and a standard deviation of one.

Data analysis: SES indicator applied to WASH

WASH indicators

The ECoMiD study collects information on multiple household-level WASH access components, categorized to facilitate aggregation aligned with the WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) service levels.[142] These include household toilet type (reported and observed): toilet that discharges to a sewer system, toilet that discharges to a septic tank, toilet that discharges to a pit latrine, toilet that discharges to another place, improved and ventilated pit latrine, pit latrine with slab, pit latrine without slab, composting toilet, plastic bucket, hanging toilet, open defecation; main source of water for drinking (reported): tube well, protected well, unprotected well, protected spring, unprotected spring, surface water – river, surface water – stream, piped water connections, public tap, small tank truck, rain water, bottled water; and presence of a handwashing station (any type) and presence of 1) soap and 2) water in the handwashing station (observed).

Of the WASH priorities identified in the qualitative work, household ownership information was available from the ECoMiD survey data specifically for water tanks, water drums, cisterns, showers, and piped water connections. Survey data also captured broader information on identified WASH priorities including main reported source of household drinking water and household bathroom type, as described above.

Defining "complete" household WASH

A binary indicator of "complete" household WASH was created for data analysis. This indicator is comprised of three separate household WASH indicators. We chose to use the composite indicator because there was limited variability in the dataset among the individual

components. First, we generated a binary indicator of a household having basic or limited water services versus unimproved or surface water, based on JMP definitions.[142] We used the same process to create a binary indicator of a household having basic or limited sanitation services versus unimproved or open defecation. Although safely managed water and sanitation services are considered the safest type of service provision by JMP, we lacked the specific data needed to estimate coverage of these indicators in the study population. Lastly, an indicator of household hygiene was created as binary presence of a handwashing station with soap and water present versus missing any aspect, also in line with JMP definitions of "basic" hygiene. To be categorized as having complete household WASH, a household had to have a "1" for all three of these indicators, i.e., have at least basic or limited water, at least basic or limited sanitation, and basic hygiene. We also compared the functionality of using the underlying components of the indicator individually versus the composite indicator.

Covariates

Remoteness, defined as site on the urban-rural gradient (urban, intermediate, rural-road, rural-river), was included as a covariate to account for potential community-level clustering.

Application to the SES-WASH pathway

We analyzed the qualitative and quantitative results jointly, and findings are presented in joint displays throughout.

Main analysis. We used a multivariable logistic regression model to estimate the effect of wealth (scaled continuous version of the asset-based SES indicator with mean 0 and standard deviation (SD) 1) on the odds of having complete household WASH (binary), adjusting for remoteness.

Comparative analysis. We repeated the main analysis using the individual components of the complete household WASH indicator (basic or limited water, basic or limited sanitation, and basic hygiene) as the outcome for our comparison.

Stratified analysis. We also conducted a descriptive stratified analysis to explore if there was a threshold of wealth for ownership of key items identified in the qualitative interviews, comparing prevalence of ownership across wealth tertiles.

Ethical approvals

The ECoMiD study was originally approved by institutional review boards at Emory University (IRB00101202) and the Universidad San Francisco de Quito (2018-022M), and is currently overseen by the University of Washington (IRB 00014270) and USFQ. It was additionally approved by the Ecuadorian Ministry of Health (MSPCURI0002534).

RESULTS

Part 1: Qualitative perspectives on possessions and wealth

The results from the freelist activity and ranking activity, as well as qualitative feedback from mothers from the open-ended questions, brought to light a number of considerations for using asset ownership as a proxy for SES.

ECoMiD mothers freelisted stoves (listed by 82% of mothers), refrigerators (73%), televisions (55%), beds (52%), and washing machines (36%) most frequently as the most important physical items they owned (or could own) (Table 1). Although the exact ordering of the most frequently mentioned items varied by remoteness, the top items were generally consistent. Water was specifically mentioned as important by 18% (n=6) of the mothers that were interviewed.

Assets that were most valued by mothers were not necessarily correlated with an item's price. Rather, mothers tended to focus on what was needed to provide for their children, and the items that would help save time for themselves (e.g., TVs to entertain children while they did chores) (Table 1). Food insecurity is a major issue in the region, and many mothers discussed that they would prioritize buying food, as well as medicine, over durable household items. Mothers also mentioned wanting to save money for emergencies or for education, rather than spending it on material goods (Table 1).

Many mothers expressed that the assets they owned depended on their own specific priorities, which related to what material goods were already available to them (e.g., a home they own versus rent). Further, mothers frequently expressed using social capital (parents, in-laws) to obtain access to housing, durable goods, and WASH access.[134] In many interviews, mothers imagined that community members might also borrow expensive assets from friends,

receive them as gifts, or win them in bingo, highlighting the complex relationship between the accumulation of household assets and an item's expense.

> *"I could have a scooter but not own my own home because I live with my mother, for instance… the house is the most important thing for me, it is my priority, but it could be that for someone else, their priority is to have a scooter, and so they will invest in that [instead]" [3124]*

Maternal considerations likely also influenced how mothers responded when asked to categorize items as something anyone of any economic class could own, something the middle class and above could own, or something only the wealthiest could own. Mothers ranked hot plates, air conditioners, exercise machines, boats with motors, video cameras, and cars and trucks most frequently as items that would be owned only by the wealthiest class (Figure 2). Radios, electricity, blenders, gas stoves, irons and mobile phones were most frequently categorized as something anyone could own.

Mothers tended to classify items that were frequently freelisted as important to own (TV, refrigerator, washing machine) as similarly accessible to all social classes as assets with much lower relative costs (wrist watch, sandwich maker) (Figure 2). Maternal priorities translated to actual ownership as well: ownership of assets that mothers thought anyone could own (radios, mobile phones) was lower compared to ownership of assets that mothers thought were most important to own (e.g., radio and mobile phone ownership <50%; TV and refrigerator ownership >80% across all households, Supplemental Table 2). Ownership of the most expensive items (e.g., cars and trucks) was extremely low across the study population. This indicates that reasons for non-ownership of an asset relate to perceived essentialness and/or affordability, depending on the asset, rather than on price alone.

There was some variation in rankings by site (Supplemental Figure 1), most notable in the rural-river communities, where showers and microwaves were more often ranked as items only the wealthy could own, while washing machines were considered something anyone could own.

Interestingly, ownership of washing machines was also highest in the rural-river sites, further demonstrating how interconnected maternal priorities and ownership can be irrespective of costs.

Mothers postulated that the rich would likely have the same assets as them, but bigger, nicer, or in greater quantities. This suggests that asset quality and quantity are also important indicators of relative wealth.

> *"In the lower class, a household has their small furniture, a small stove, while in the middle class they have big things, big dining table and chairs, big furniture, a nice TV, here there is just a tiny one." [2237]*

Finally, the interviews made clear that despite past validation of the possessions included in the original ECoMiD survey and inclusion of nationally validated possessions, many of the assets included in the ECoMiD survey were not well understood by interviewees, and at times not by the field team. In some cases, interviewees did not know what a question was referring to at all (hot plate, cart pulled by animals, speaker). For other assets, there was some confusion about what, exactly the word referred to (motor vs. generator, iron for hair vs. iron for clothes, motorcycle vs. smaller scooter locally referred to as a pasola), or mothers felt a multitude of interpretations were possible that spanned expensive to cheap options (boat with motor, shower).

> *"Interviewer: Have you heard of a hot plate?*
>
> *Mother: No, but I imagine it must be something the upper classes have, in that case." [2414]*

It is clear from the rankings that when mothers were uncertain about an asset, they tended to assume it was something a wealthier person would own, but in many cases, it is difficult to know what exactly a mother was envisioning when responding to ownership questions for possessions like a shower or a speaker. Items mothers were unfamiliar with or which had very different possible interpretations are marked with an asterisk in the rankings results to reflect this uncertainty.

Part 2: SES indicator creation

We used the qualitative results to improve and refine the initial asset-based measure by dropping assets that were not well or consistently understood by participants (cart drawn by animals, boat with engine) from the final MCA. In addition, although mothers identified air conditioners, exercise machines, and video cameras as most representative of wealth, only one household in the dataset reported owning an air conditioner and exercise machine, and none reported owning a video camera. Among other top ranked indicators of wealth, <=3% of households reported owning cars or trucks, or scooters. Due to low prevalence, these assets were also excluded from the final MCA.

Ownership of the final set of 11 assets included in the MCA is summarized by remoteness in Supplemental Table 2b. Ownership was highest overall for televisions (89%) and refrigerators (80%), and ownership for both was highest in the urban site. Computer and internet ownership were also highest in the urban site, while motorcycle ownership was highest in the rural-road communities. Less than 50% of households reported owning cell phones, and ownership was highest in the intermediate site. Differences in ownership by remoteness site were statistically significant ($p<=0.05$) for all but two of the eleven items included (Supplemental Table 2b). The first dimension of the final MCA explained 85% of overall variance after applying the Benzécri correction, driven primarily by owning a computer, microwave, and the internet. These items were frequently identified as things a middle- or upper-class household would own in the ranking exercise.

Overall, the final asset-based SES scores tended to follow a decreasing trend by remoteness, where they were highest in the urban site (mean 0.14), followed by the intermediate site (mean -0.01), and the rural-road communities (mean -0.06), and lowest in the households in the rural-river communities (mean -0.14) (Figure 2, Supplemental Table 3). There

was substantial overlap in scores between the four sites, with outliers of higher SES in all sites. The lowest household scores were also similar across the sites.

Once disaggregated by community, the mean scores in Colon Eloy, a rural-road community, and in San Francisco, a rural-river community, were higher than in Borbón, the intermediate community (means of 0.01 and 0.07, respectively). Colon, a rural-river community, had the lowest mean wealth score overall (mean -0.24). The total number of ECoMiD participants from these communities is small, and as such the results should be interpreted with caution. The final asset-based SES score appeared to measure wealth in the same way across sites on our urban-rural gradient compared to other SES proxies (see Supplemental Table 4).

Part 3: SES indicator applied to WASH

In the ECoMiD survey data, the percentage of households reporting bottled water as their primary drinking source was high overall (46%) but highest among households in the top third of the wealth distribution (54%) (Table 2). Rain water was much less likely to be the main reported source of drinking water among the wealthiest households (6%) compared to the poorest (16%). The percentage of households reporting piped water as their primary drinking source was similar across wealth tertiles (ranging from 24% to 33%), but wealthy households were much more likely to have a piped connection in their home (74% wealthiest vs 47% poorest). When considering only households that had a piped connection, the wealthiest households were less likely than other wealth categories to report it as the main source of water for consumption (32% vs 42-48%, Supplemental Table 5) and more likely than other wealth categories to report bottled water for drinking (56% vs 39-48%).

Few households in the study population reported sharing their primary drinking water source with other households (<10% in any location), but the rate was lowest among the wealthiest households (4%). This difference was starker for the percentage of households who reported

sharing their bathroom with others (14% of the poorest households vs 2% of the wealthiest, Table 2). There was a clear trend of “safer” bathroom types and wealth: the wealthiest households were much more likely to be connected to a sewer system (47% of the wealthiest vs 24% of the poorest households) and much less likely to own unimproved sanitation facilities such as toilets connected to pits, pit latrines without slabs, buckets, or hanging toilets, or to practice open defecation. The percent of households with observed stool on the bathroom floor, around the house, or animal feces around the house were low across the study population (<5% for the human stool and <10% for animal overall), but it was observed the least frequently in the wealthiest households.

Complete household WASH

There was a clear trend of increasing coverage with complete household WASH by wealth tertile, with 51% of households in the poorest tertile having complete household WASH compared to 73% of households in the wealthiest tertile (Table 3a). However, there was potentially a high wealth threshold for complete coverage, as coverage in the middle wealth tertile (57%) was just 6% higher than the poorest tertile. This threshold by tertile was also apparent within remoteness sites, where coverage increased from 60 to 65-73% in the urban site, from 41 to 52-70% in the intermediate site, from 58 to 55-74% in the rural-road communities, and from 46 to 56-82% in rural-river communities (Supplemental Table 6).

Between the lowest and highest wealth tertiles, coverage with basic or limited sanitation improved from 85% to 98%, while coverage with basic or limited water was the same across wealth tertiles (97%, Supplemental Table 7a). Coverage with a supplied handwashing station increased from 62% to 77% and was the only component of household WASH to display more of a threshold trend, increasing just 1% from the lowest to the middle tertile.

The number of households with complete household WASH was relatively low overall (60% of all households), and highest in the urban site (67%; Table 3b). There was not a consistently increasing trend in coverage by remoteness: coverage was lowest in the intermediate site (53%) followed by the rural-river communities (57%) and then rural-road (62%) and the urban site. When disaggregated by community, distinct variation was apparent within the rural-river and rural-road communities, but the low total number of participants in several of the sites makes interpretation difficult (Supplemental Table 8). For instance, the MIDUVI households in Borbón (N=4) had comparatively higher levels of coverage with complete WASH (75%) despite being mostly in the lowest wealth tertile (75%).

Among the components that make up the complete household WASH indicator, coverage of basic or limited water was high across communities (90% or higher) and coverage of basic or sanitation was high (>88%) in all communities except Colon (21%) (Supplemental Table 7b). Coverage with a supplied handwashing station was lower in the intermediate site (60%) and the urban site (69%) compared to other locations.

Threshold of wealth results for priority WASH items

Ownership of WASH priority items identified by mothers was low across the study population: for example, just 6% of households reported owning a cistern, though ownership was highest in the wealthiest tertile (11%) (Supplemental Table 9a). By site, cistern ownership was highest in the urban site (15%) and no households in the rural-river communities owned a cistern (Supplemental Table 9b). Within each community, distribution of cistern ownership tended to be concentrated in the highest wealth tertiles and was extremely low or absent in the lowest wealth tertiles (Supplemental Table 9c).

There was an inverse relationship comparing the wealth-ownership trend for water drums (smaller and cheaper than cisterns and elevated tanks) to cisterns or to combined cistern or elevated tank ownership (Supplemental Figure 2, Supplemental Table 9a), with ownership of

drums becoming less prevalent with increasing wealth. Drums were extremely prevalent in the rural-river communities (93%) and decreased in prevalence along the urban-rural gradient, with a low of 17% ownership in the urban site (Supplemental Table 9b). Although within many communities, the bottom tertile had the greatest prevalence of water drum ownership (Borbón, Colon, Esmeraldas, Selva Alegre), there was not consistently a clear gradient of ownership by wealth within each community (Supplemental Table 9c).

Shower ownership was similarly low overall at just 18%, ranging from 11% in the poorest tertile, to 16% in the middle, and 28% in wealthiest tertile (Supplemental Table 2). Shower ownership was lowest in the rural-river communities (just one household) and the intermediate site (15%), compared to the rural-road communities and the urban site (20% and 26%, respectively).

Regression model results

Wealthier households had an estimated 1.7 (95%CI 1.4-2.1, p<0.0001) times the adjusted odds of having complete household WASH, comparing two households differing by one SD of wealth (Figure 4). Wealth was associated with higher access to all three components making up this indicator, and was most strongly associated with access to basic or limited sanitation (OR 3.5; 95%CI 1.8-7.1), compared to basic or limited water (OR 1.5; 95%CI 0.7-3.5) or basic hygiene (OR 1.6; 95%CI 1.3-2.0).

DISCUSSION

As hypothesized, we found that greater household wealth translated into better household WASH, both with respect to ownership of specific hardware and products, and in terms of estimated odds of having complete household WASH coverage and particularly limited or basic sanitation. Our data provide quantitative estimates of the wealth-WASH relationships, and suggest there may be a high threshold of wealth necessary to achieve complete WASH coverage and to own priority WASH items like cisterns. Mean wealth scores were lowest in the most rural sites and highest in the most urban. The relationship between wealth, WASH, and remoteness was less clear, potentially due to diverse infrastructure conditions within sites, government-provided housing, and variability in home ownership.

Qualitative information from mothers in the ECoMiD cohort indicate that there is unlikely a perfect correlation between increasing wealth and accumulation of expensive assets; rather, affordability, household status, and priority interact to inform household purchases, from cellphones to WASH infrastructure, highlighting the importance of understanding household preferences. Despite known limitations of using asset-based SES indicators, our review of the adequacy of the measure indicates that this measure likely captures household wealth better than other, comparable measures in our population, particularly for assessing household WASH conditions.

The wealth – WASH pathway

Households in the top tertile of the wealth distribution had the highest levels of complete WASH coverage.[46,143] Although estimating the relative impact of safely managed water, sanitation, and hygiene in the household is complex, all three components have the potential to interrupt enteric disease transmission, have been connected to reductions in the diarrheal disease burden, and are associated with long-term outcomes such as stunting.[31–35] Our analysis found that wealth is associated with increases in coverage for all three independently.

It was difficult to estimate differences in water coverage due to universally high coverage with basic or limited water in our study population. Our estimates for water access are similar to the JMP 2022 estimates for Ecuador,[142,144] which reported that 88% of rural and 100% of urban residents had access to basic or limited water and above, though notably our rural sites tended to have coverage over 88% and our urban site was slightly below 100% coverage. Further, JMP data from 2022 estimated that just 53% of rural populations and 75% of urban locations had access to *safely managed* water, an indicator we were not able to estimate with precision for our population.

We found that wealth was most strongly correlated with increased coverage with limited or basic sanitation. This result was likely driven largely by a single, rural-river community, which had substantially lower access to basic or limited sanitation compared to the other ECoMiD communities, and relatively low wealth scores. The relatively small sample size in that community likely explains why the estimate for the composite indicator is closer to that of the water and hygiene estimates.

Overall, sanitation coverage levels in our communities were similar to the national rates reported by JMP: 90% of rural populations and 93% of urban populations in Ecuador have access to basic or limited sanitation or above.[142,144] However, the much lower levels of access to safely managed sanitation highlight the challenges of providing these services, particularly in urban populations: 61% of rural and just 31% of urban populations nationally were estimated to have this safest coverage level, which we were also unable to estimate with precision. For handwashing station with soap and water, our community coverage levels were below the JMP estimates in many sites, which report that 79% of rural and 92% of urban households in Ecuador have access to this basic hygiene resource. Hygiene coverage was actually lower in our more urban sites compared to our more rural sites.

In part due to the lower levels of access to basic hygiene, coverage with the composite indicator of complete household WASH was low among our study households considering the global target of 100% access to safely managed WASH. Had we been able to estimate safely managed access, it is likely that a much smaller percentage of study households would have qualified.

The health benefits of having complete WASH coverage are limited by water intermittency, contamination, and improper waste disposal, among other factors, particularly for poorer households. The potential equalizing nature of public infrastructure may be limited by system quality. For example, a study that assessed safely managed drinking water services across 27 low- and middle-income countries found that the poorest households were much more likely to consume water contaminated with *Escherichia coli* (the main constraint to safely managed access in their study) compared to the wealthiest households.[145] Further, our coverage estimates do not capture additional elements of user preference/satisfaction or labor, which can overly burden the poorest households.[28]

Despite the limitations of these measures of WASH access and the variation in infrastructure quality in our study communities, having access to an improved toilet and improved water was associated with lower rates of enteric infection in a recent study of 6-month old infants in our study site.[146] Given the dual concentration of wealth and infrastructure in the urban site of Esmeraldas, we would expect to see the greatest health benefits there, and indeed, our recent study also found that infants in that remoteness site had the lowest rates of enteric infection.[146]

Threshold effects

We detected some evidence of a threshold effect between household wealth and WASH coverage: only at high levels of wealth were households likely to report complete household WASH coverage and ownership of specific priority WASH hardware, like cisterns. This aligns

with other research, which suggest that a high level of WASH and wealth is required to prevent poorer health outcomes. For example, a study conducted in the Gambia found that there may be very high thresholds of wealth needed to achieve improvements in child growth, an outcome often targeted in WASH interventions.[123] Given these results, it is probable that poverty alleviation efforts, such as existing cash transfer programs, in addition to existing or new WASH interventions that suit local residents and target the poor, would need to be scaled up substantially to overcome these high thresholds for WASH ownership. Increased investment in WASH service delivery has been called for by the UN and others monitoring progress on global WASH indicators.[147,148]

Individual perspectives and behaviors

We found that household asset accumulation depends on a combination of financial resources and personal priorities, which is in alignment with our past research exploring maternal prioritization and purchasing of WASH-related products and hardware.[134] Community members in our study are well aware that piped water can be contaminated and can make them sick (see quote, Table 3), and that wealth grants access to alternatives, primarily in the form of bottled water (see quote, Table 2). Wealthy households were more likely to have access to piped water in their home—and the non-financial benefits of saved time and labor[30,102,134]—but among those with household connections, the wealthy were the least likely to report piped water as their primary drinking source, instead relying on bottled water. Bottled water consumption is a much less sustainable form of water access compared to piped systems.[93] In addition, purchasing bottled water places a disproportionate burden on the poorest households,[93,149] and individuals who are already paying for piped water connections that they don't trust as safe to drink are effectively paying for their water twice.

Households in the top wealth tertile were also much less likely to report using rain water, despite it being considered an improved water source, likely due to the associated labor burden,

which is not captured in the JMP service hierarchy. Wealthy households also had higher ownership of improved types of bathrooms, particularly sewer connections. It is probable that this is due in part to the concentration of wealth in the urban site, the city of Esmeraldas, one of the only locations where sewer infrastructure is in place. In other communities, MIDUVI households were more likely to have access to a pre-built bathroom, piped water connection, and handwashing station, but they are not guaranteed an actual connection to the public water system or a functional sewer (see quote, Table 2).

The interaction between personal priorities and preferences related to WASH likely impacts the relationship between wealth and water hardware ownership. For instance, no households in the rural-river communities owned a cistern, and in our prior qualitative work, we found that households in those communities felt that the risk of flooding and geographic unsuitability lowered the desire for cisterns, despite perceived benefits to water access in the household.[134] As such, increased wealth in these communities may not correlate with ownership of priority items. Interestingly, ownership of water drums decreased with increasing wealth, likely because, as wealthier households invest in larger water storage containers like cisterns or tanks, they no longer need to rely on smaller drums.

Household and community factors

Wealth also influences the community or neighborhood a household is able to live in (with or without high quality public infrastructure) and the type of home (owned, rented, borrowed from family inherited; standard, government funded, informally settled) in which they may or may not want to invest in WASH improvements. The most complex interpretation issues for the asset-based SES indicator in our study context are likely around interpreting wealth under these different contexts. For example, wealthier, formally incorporated communities, and/or those with higher social cohesion, may be better able to advocate for improved public services at the community level. At the household level, landlords are responsible for installing WASH

hardware in rentals and the government in MIDUVI households, and so wealth may not directly correlate to household WASH status. Families in informal settlements or borrowed homes may not want to invest in expensive, long-term WASH solutions, irrespective of wealth. Lack of home ownership has also been identified as a driver of inequitable lack of access to WASH that is in turn dictated by racism and social exclusion.[150] These elements may modify the ultimate wealth – WASH relationship in complex ways.

Appropriateness of the asset-based SES indicator

Compared to other potential SES indicators available in our dataset, our asset-based measure appeared to measure wealth adequately and similarly across locations. Qualitative findings did bring to light some limitations of using the asset measure: mothers described that a combination of personal priority and social capital might drive ownership of expensive assets, mixing the drivers of possession ownership with non-financial aspects. Other spending priorities highlighted as important by mothers, such as food security and children's education, are not well captured in this indicator. In addition, ownership of the items mothers expressed were most likely to be owned only by the wealthiest households was low, which presented a challenge in distinguishing between poverty levels using the existing assets. However, the alternatives were subject to their own set of limitations for use (see Supplemental Methods).

In the literature, concerns with using asset-based indicators include 1) potential differences in the relative value of possessions in rural versus urban locations, 2) changes in the value of possessions over time and issues around distinguishing the relative quality of a possession, and 3) the static nature of durable assets.[137–139,151] For 1), our area under the curve analysis indicated that the asset-based measure performed similarly across remoteness sites compared to other proxies of SES. For 2), we identified a number of assets for which changing value overtime has made them somewhat out-of-date for inclusion (e.g., DVD player, video camera). However, the change in value over time should affect all our households in the same manner,

and not greatly impact the MCA results. Differences in the quality or quantity of an asset are more of a challenge to capture via MCA. For 3), as our outcome of interest is household WASH products, hardware, and infrastructure, having a static wealth measure is suitable for our relatively static outcome. Overall, our results indicate that local validation of asset-based SES measures is important and needs to be updated regularly. Ultimately, our review and consideration of alternate SES indicators suggested that the final asset-based SES indicator could be carried forward into our analysis of the SES – WASH pathway, despite limitations. Similar studies that have sought to validate the use of asset-based SES indicators have also found them to be valid for analysis.[152]

Conclusion

Our regression models showed that wealth was significantly related to increased household WASH coverage in our study population. Our results indicate that a high threshold of wealth may be needed to own priority WASH items, like cisterns, and to achieve complete coverage with basic or limited water, sanitation, and hygiene at the household level. Together, our findings highlight the importance of poverty alleviation in achieving WASH equity. Wealth, individual preferences and priorities, community infrastructure and quality, and housing status all likely influence the effect of WASH interventions on health outcomes, and may help explain potential limitations of existing WASH interventions. Correctly accounting for SES is crucial for studies analyzing the benefits of and barriers to equitable WASH access and corresponding health benefits.

TABLES AND FIGURES

Table 1: Maternal perceptions of important household assets. Frequency (n) and relative frequency (%) with which household possessions were freelisted by ECoMiD mothers, in any order, in response to the prompt: what are the most important things you and your family own? Darker blue shading represents higher frequency of the asset being listed overall and by remoteness. Illustrative open-ended responses related to wealth and possessions shown alongside the frequency table.

Household Possessions	Overall (N=33)		Urban (N=8)		Intermediate (N=9)		Rural-Road (N=8)		Rural-River (N=8)		**Qualitative responses to "What are the most important things you own?"**
	Freq	Rel. Freq	Freq	Rel. Freq	Freq	Rel. Freq	Freq	Rel. Freq	Freq	Rel. Freq	
Stove	27	82%	7	88%	9	100%	5	63%	6	75%	"A stove to cook for my children, a TV to entertain them, a washing machine to wash their clothes, a freezer to sell my [treats], a refrigerator to store their food, so they can drink cold water, a place for them to sleep, a blender to make them juice." [2331]
Refrigerator	24	73%	8	100%	6	67%	5	63%	5	63%	
TV	18	55%	4	50%	6	67%	5	63%	3	38%	
Bed	17	52%	4	50%	4	44%	3	38%	6	75%	
Washing machine	12	36%	3	38%	5	56%	3	38%	1	13%	
House	8	24%	1	13%	1	11%	2	25%	4	50%	"The most important thing is my son… The stove to cook his food… the bed he sleeps in… the refrigerator to keep his things healthy… My own house, for my children. We rent this one, so it would be good to have our own home." [1216]
Water	**6**	**18%**	**1**	**13%**	**2**	**22%**	**2**	**25%**	**1**	**13%**	
Gas	5	15%	2	25%	1	11%	2	25%	0	0%	
Furniture	4	12%	0	0%	2	22%	1	13%	1	13%	
Bathroom	3	9%	0	0%	1	11%	1	13%	1	13%	
Matress	3	9%	1	13%	0	0%	1	13%	1	13%	**Qualitative responses to "If you had $1,000 to spend on material things, what would you buy?"**
Blender	2	6%	0	0%	1	11%	1	13%	0	0%	
Plates	2	6%	0	0%	1	11%	1	13%	0	0%	
Freezer	2	6%	0	0%	1	11%	0	0%	1	13%	
Air Conditioner	1	3%	0	0%	0	0%	1	13%	0	0%	
Dresser	1	3%	0	0%	1	11%	0	0%	0	0%	
Dinning table	1	3%	0	0%	1	11%	0	0%	0	0%	"If I had [money] I would build my house to be with my daughters and help them so they keep studying, so they can be someone in life." [3207]
Cups	1	3%	0	0%	0	0%	1	13%	0	0%	
Mirror	1	3%	0	0%	0	0%	0	0%	1	13%	
Stereo	1	3%	0	0%	0	0%	0	0%	1	13%	
Farm	1	3%	0	0%	0	0%	0	0%	1	13%	
Dining set	1	3%	1	13%	0	0%	0	0%	0	0%	What would I buy with a thousand dollars? What would I buy except for food, just food." [4012] "For me the most important thing in life is being healthy, and having food for my children." [11]
Furniture set	1	3%	1	13%	0	0%	0	0%	0	0%	
Microwave	1	3%	0	0%	0	0%	0	0%	1	13%	
Motorcycle	1	3%	0	0%	0	0%	1	13%	0	0%	
Rice cooker	1	3%	0	0%	0	0%	0	0%	1	13%	"The important things aren't material, [the money] is important so that my children can study, so that I can sustain them... You might think my house has very little, but my children don't go hungry, that is the important thing for me." [4014]
Iron	1	3%	0	0%	0	0%	0	0%	1	13%	
Telephone	1	3%	0	0%	0	0%	1	13%	0	0%	
Toaster	1	3%	0	0%	0	0%	0	0%	1	13%	
Fan	1	3%	0	0%	1	11%	0	0%	0	0%	

Table 2: Water, sanitation, and hygiene characteristics of ECoMiD study households by wealth tertile. Data from ECoMiD surveys (N=521), quotes from qualitative interviews (N=33).

	Poorest (N=174)	Middle (N=174)	Wealthiest (N=173)	Overall (N=521)	*P*-Value
Main source of water for consumption	*"I think that here, most people drink the piped water, because not all of us can buy the water. I don't, we don't drink this water, but most people who don't have the means to buy water, drink the piped water… they will get sick, it will make them sick to their stomachs, it isn't good water." [3207, Rural-Road Site]*				
Bottled water	74 (42.5%)	71 (40.8%)	94 (54.3%)	239 (45.9%)	
Piped water connection	42 (24.1%)	57 (32.8%)	48 (27.7%)	147 (28.2%)	
Public tap	8 (4.6%)	13 (7.5%)	13 (7.5%)	34 (6.5%)	
Rain water	27 (15.5%)	21 (12.1%)	10 (5.8%)	58 (11.1%)	
Small tank truck/drum	0 (0%)	1 (0.6%)	0 (0%)	1 (0.2%)	0.004
Protected well	12 (6.9%)	5 (2.9%)	3 (1.7%)	20 (3.8%)	
Tube well	0 (0%)	2 (1.1%)	2 (1.2%)	4 (0.8%)	
Surface water - river	9 (5.2%)	1 (0.6%)	1 (0.6%)	11 (2.1%)	
None	1 (0.6%)	1 (0.6%)	1 (0.6%)	3 (0.6%)	
Other	1 (0.6%)	2 (1.1%)	1 (0.6%)	4 (0.8%)	
Share main water					
Yes	12 (6.9%)	15 (8.6%)	6 (3.5%)	33 (6.3%)	0.16
Missing	90 (51.7%)	79 (45.4%)	86 (49.7%)	255 (48.9%)	
Piped connection					
Yes	82 (47.1%)	94 (54.0%)	128 (74.0%)	304 (58.3%)	<0.001
Days per week water					
Mean (SD)	4.63 (2.16)	4.74 (2.24)	4.82 (2.10)	4.74 (2.16)	
Median [Min, Max]	5.00 [0, 7.00]	5.00 [0, 7.00]	5.00 [0, 7.00]	5.00 [0, 7.00]	0.48
Missing	59 (33.9%)	43 (24.7%)	21 (12.1%)	123 (23.6%)	
Hours per day water					
Mean (SD)	15.0 (7.55)	17.8 (7.89)	17.9 (8.58)	17.1 (8.16)	
Median [Min, Max]	12.0 [1.00, 24.0]	24.0 [0, 24.0]	24.0 [1.00, 24.0]	24.0 [0, 24.0]	0.04
Missing	106 (60.9%)	81 (46.6%)	65 (37.6%)	252 (48.4%)	

	Poorest (N=174)	Middle (N=174)	Wealthiest (N=173)	Overall (N=521)	*P*-Value
Type of bathroom	*"Some people still just dig a hole [for a bathroom] and put some wood around it, not that many people, but a few, and the houses built by MIDUVI come complete [with a bathroom], the only thing they don't have is ceramic tiles… but they have their bathroom. There isn't a water system though, that is something that isn't easy here." [3124, Rural-Road Site]*				
Toilet - septic	72 (41.4%)	77 (44.3%)	78 (45.1%)	227 (43.6%)	
Toilet - sewer	42 (24.1%)	64 (36.8%)	81 (46.8%)	187 (35.9%)	
Toilet -pit	25 (14.4%)	17 (9.8%)	5 (2.9%)	47 (9.0%)	
Toilet - other place	4 (2.3%)	2 (1.1%)	2 (1.2%)	8 (1.5%)	
Pit latrine with slab	4 (2.3%)	2 (1.1%)	6 (3.5%)	12 (2.3%)	
Pit latrine without slab	12 (6.9%)	7 (4.0%)	0 (0%)	19 (3.6%)	<0.001
Plastic bucket	0 (0%)	1 (0.6%)	0 (0%)	1 (0.2%)	
Hanging toilet	4 (2.3%)	0 (0%)	0 (0%)	4 (0.8%)	
Improved ventilated pit latrine	4 (2.3%)	0 (0%)	0 (0%)	4 (0.8%)	
No facility/open def	2 (1.1%)	2 (1.1%)	0 (0%)	4 (0.8%)	
Missing	5 (2.9%)	2 (1.1%)	1 (0.6%)	8 (1.5%)	
Share bathroom					
Yes	25 (14.4%)	14 (8.0%)	4 (2.3%)	43 (8.3%)	<0.001
Missing	4 (2.3%)	2 (1.1%)	0 (0%)	6 (1.2%)	
Stool on bathroom floor					
Yes	10 (5.7%)	7 (4.0%)	3 (1.7%)	20 (3.8%)	0.15
Missing	1 (0.6%)	0 (0%)	0 (0%)	1 (0.2%)	
Stool around the house					
Yes	7 (4.0%)	6 (3.4%)	1 (0.6%)	14 (2.7%)	0.11
Animal feces around the house					
Yes	19 (10.9%)	17 (9.8%)	14 (8.1%)	50 (9.6%)	0.67

*P-values determined by fisher's exact test or chi squared test on categorical outcomes and ANOVA for continuous outcomes, statistical significance at the <0.05 level marked with *; MIDUVI=housing built by the Ministry of Urban Development and Housing*

Table 3: Complete household water, sanitation, and hygiene access by a) wealth tertile and b) remoteness. Complete access defined as access to limited or basic water, limited or basic sanitation, and a handwashing station with water and soap. Data from ECoMiD surveys (N=521), quotes from qualitative interviews (N=33).

a)

	Poorest (N=174)	Middle (N=174)	Wealthiest (N=173)	Overall (N=521)	*P*-value
Household has at least limited or basic water, sanitation, and hygiene					
Yes	88 (50.6%)	99 (56.9%)	126 (72.8%)	313 (60.1%)	<0.001
Missing	2 (1.1%)	1 (0.6%)	3 (1.7%)	6 (1.2%)	

"Sometimes we are all happy that water is available, [we think] that the water that comes to us [in the pipes] is good, but in the end it isn't. It is a really important topic to discuss when we walk about water, because, for example, in the middle class, there are those of us that have to buy water, and in the very lower class they have to drink the water that comes to them, they can't drink anything else because they don't have a way to buy it [water]… It is very important that they improve the [piped] water so that we can all have access to water like the middle class - so that our communities can drink good quality water to avoid getting diseases, because it is a way to protect us, as well." [2414, Intermediate Site]

b)

	Rural - river (N=53)	Rural - road (N=173)	Intermediate (N=163)	Urban (N=132)	Overall (N=521)	*P*-value
Household has at least limited or basic water, sanitation, and hygiene						
Yes	30 (56.6%)	107 (61.8%)	87 (53.4%)	89 (67.4%)	313 (60.1%)	0.06
Missing	1 (1.9%)	3 (1.7%)	0 (0%)	2 (1.5%)	6 (1.2%)	

P-values determined by chi squared test

Figure 1: Mixed-methods study sequence. Quantitative data collection and analysis elements shown in white, qualitative data collection and analysis elements shown in grey. SES=socioeconomic status. WASH=water, sanitation, and hygiene.

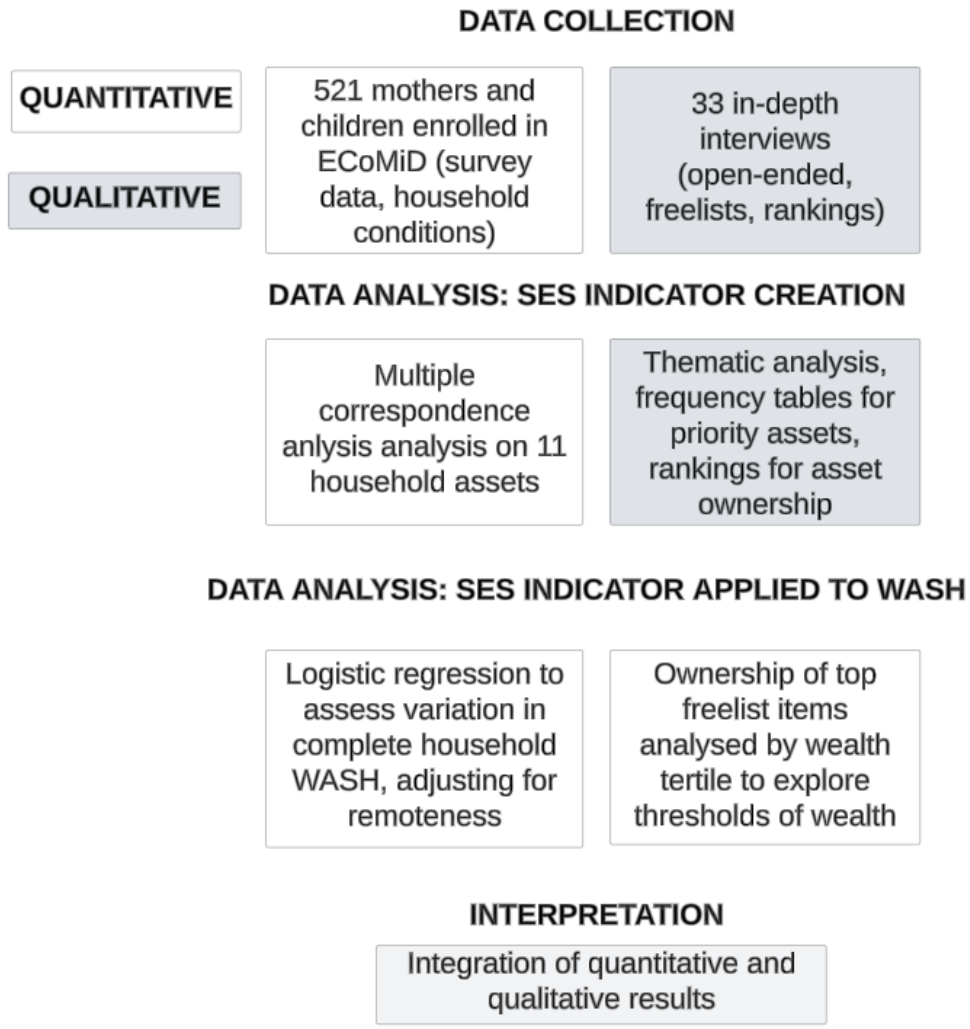
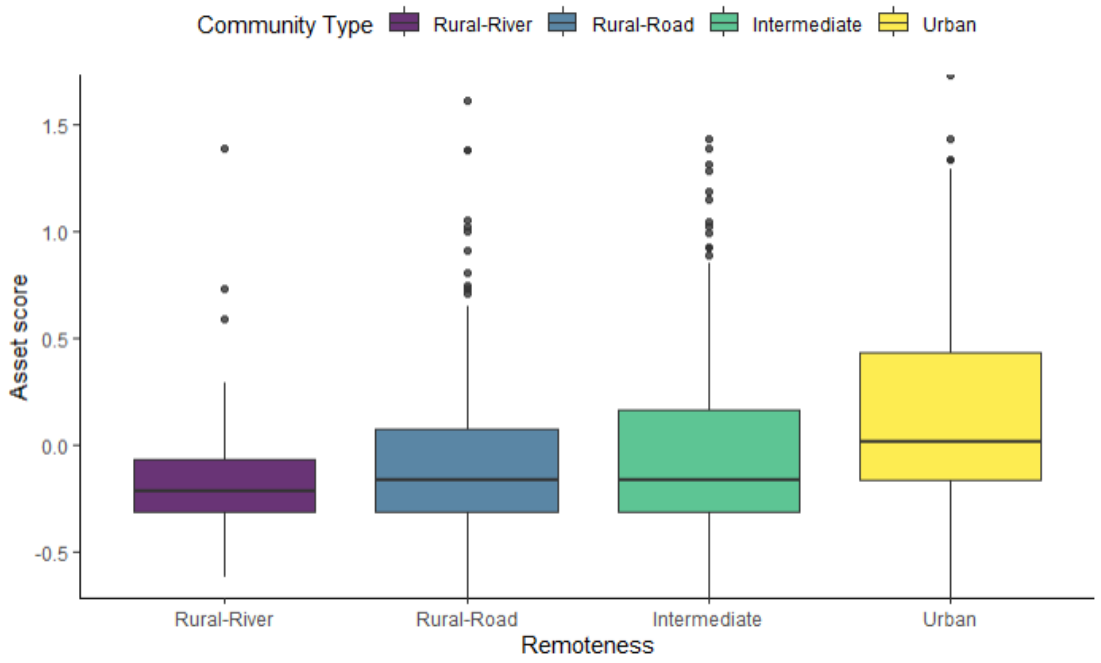


Figure 2: Final asset-based socioeconomic status score by a) remoteness and b) community. Colors indicate location along the urban-rural gradient.

a)



b)

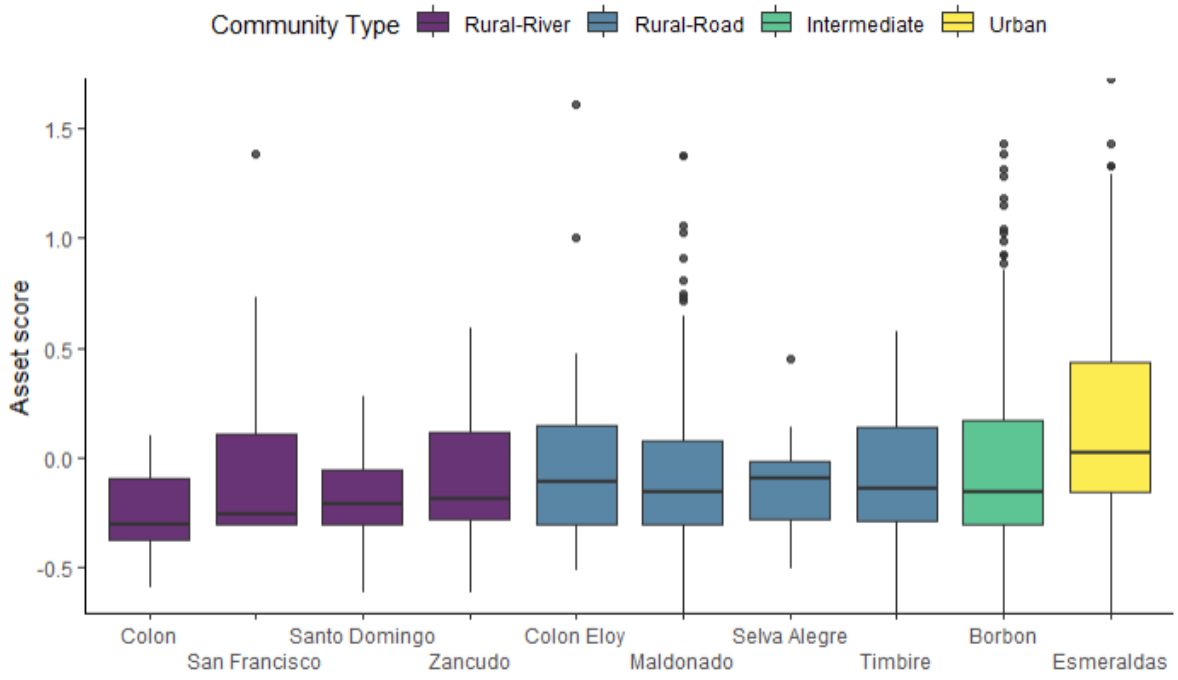


Figure 3: Asset ranking by perceived class of ownership. Colors show the percent of mothers (N=33) who classified the item as either something anyone, the poorest and above could own (purple), something the middle class and above could own (blue), or something only the wealthiest could own (yellow). Items marked with an asterisk either had multiple interpretations or were not familiar to participants

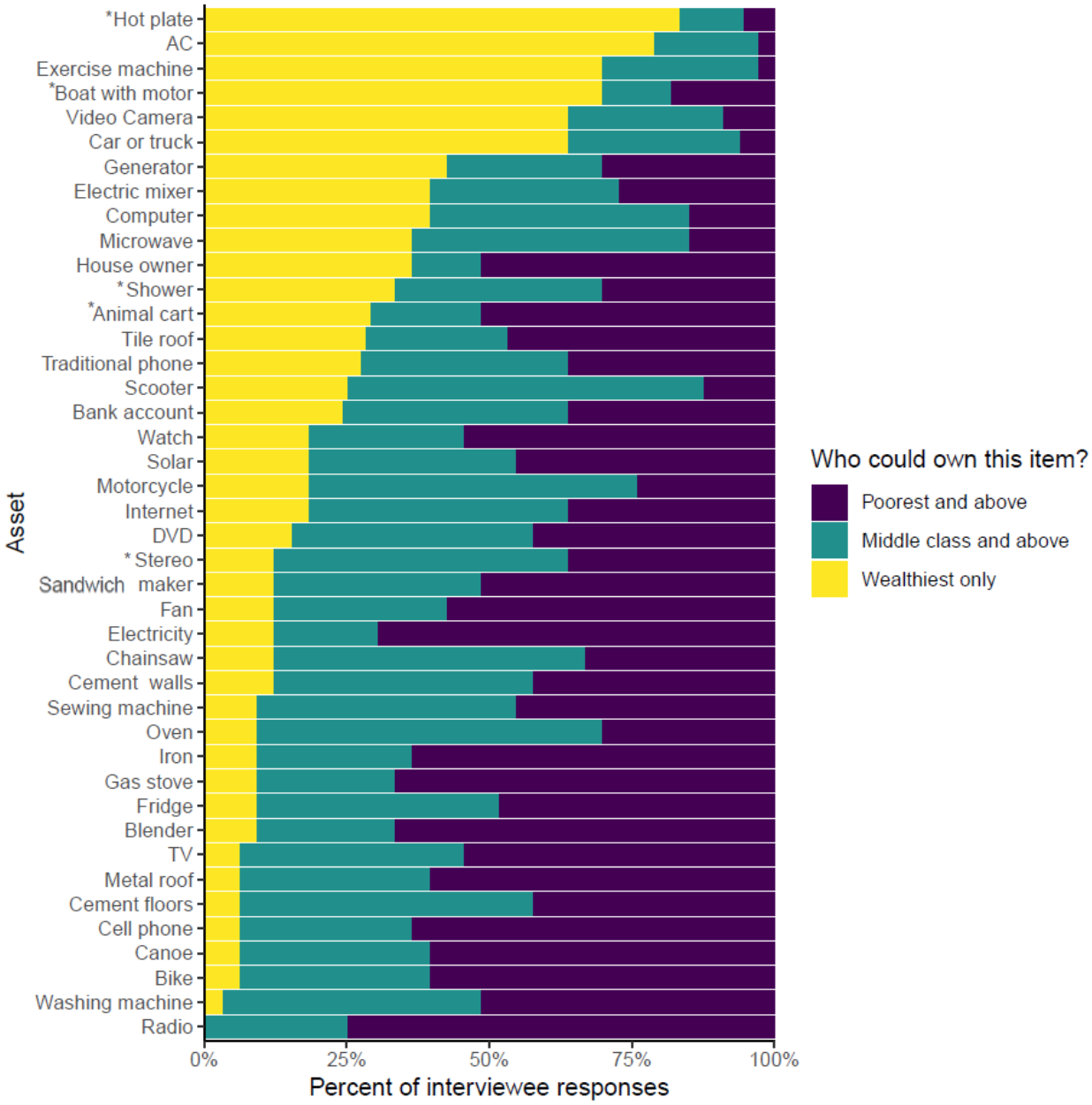
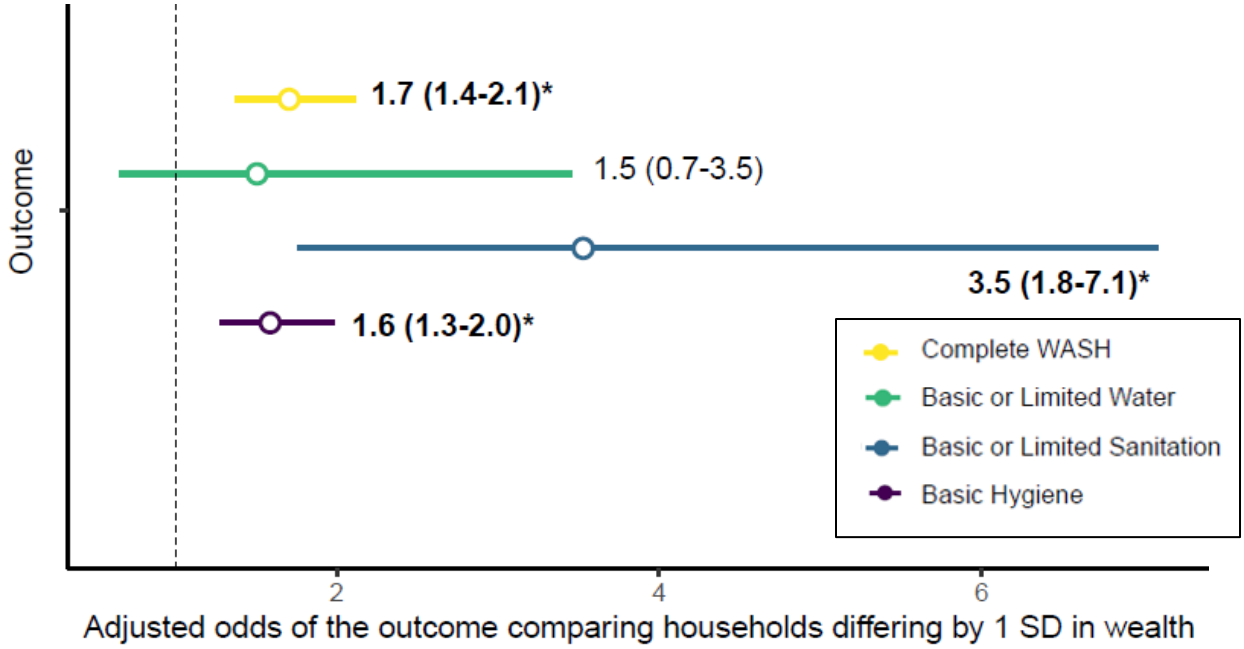
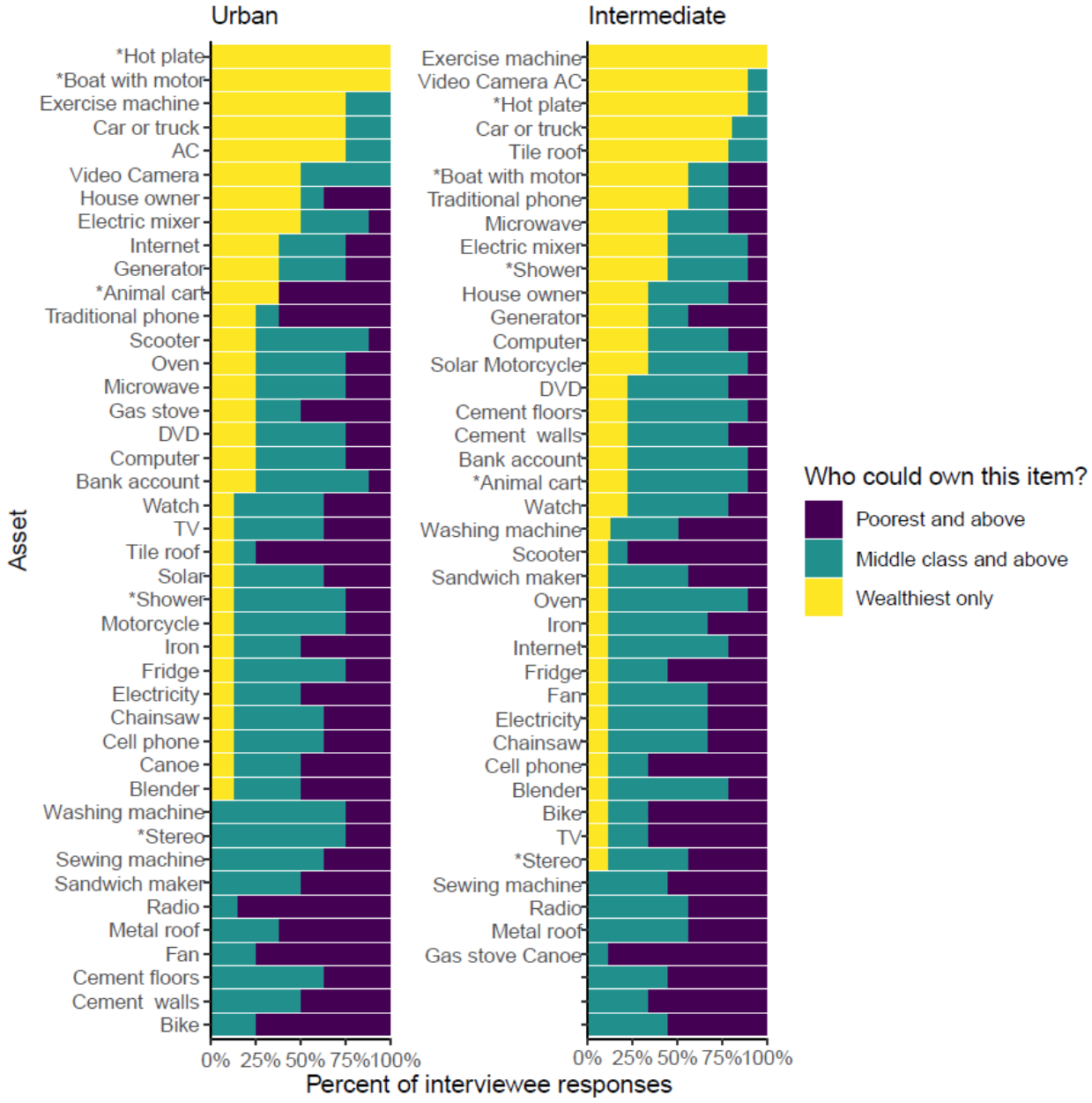
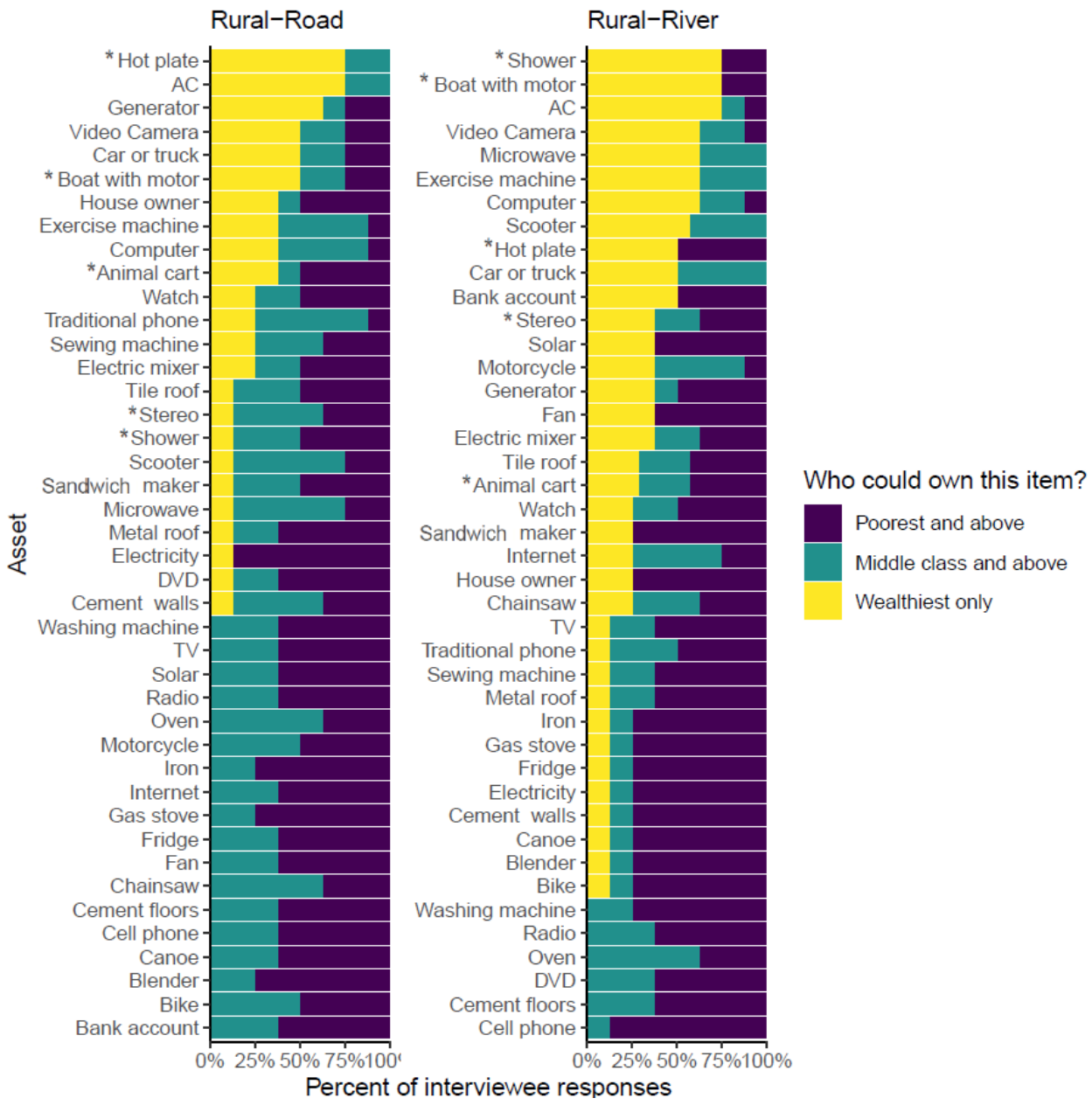


Figure 4: Logistic regression model results. Odds ratios (points) and 95% confidence intervals (lines) for having complete household water, sanitation, and hygiene (yellow), and for having each individual component (water in green, sanitation in blue, hygiene in purple), comparing two households differing by one standard deviation (SD) in wealth. All models were adjusted for remoteness on the urban-rural gradient, including Esmeraldas (urban site), Borbón (intermediate site), rural sites accessible by road (rural – road), and rural sites accessible only by river (rural – river). Odds ratios with *P*-values <0.05 shown in bold with *.



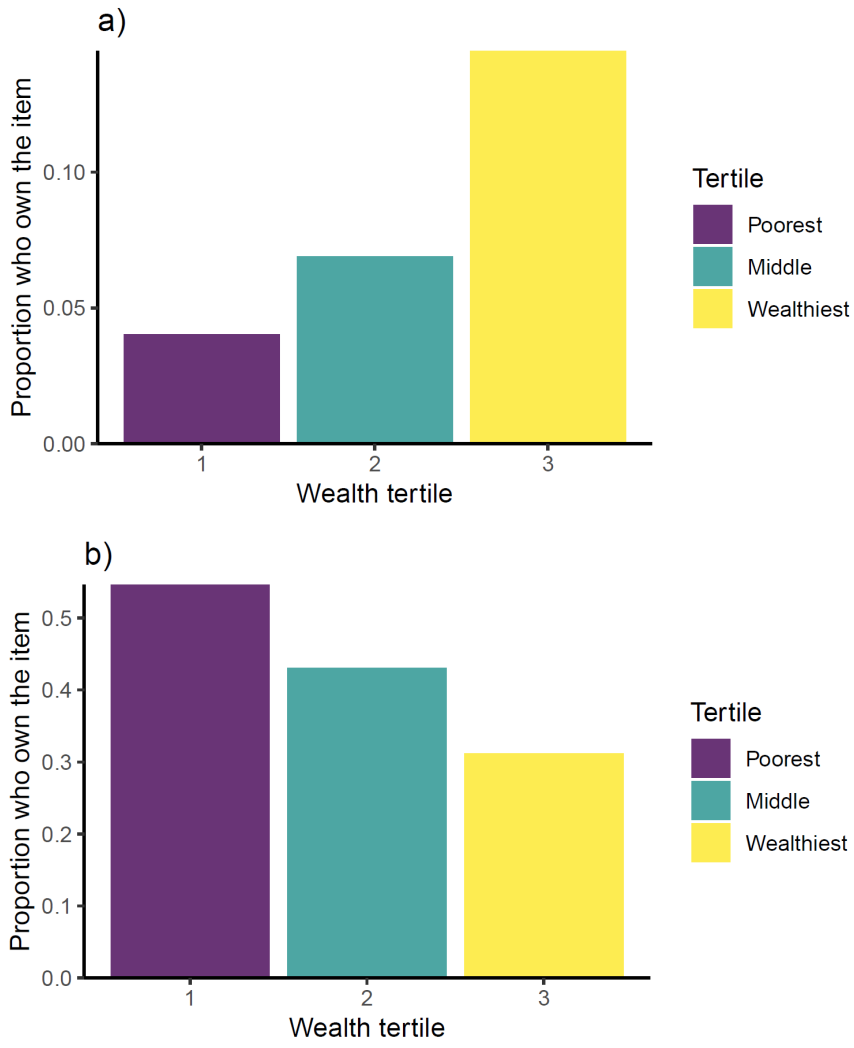
Supplemental Figure 1: Asset rankings by perceived class of ownership, stratified by remoteness. Colors show the percent of mothers who classified the item as either something anyone, the poorest and above could own (purple), something the middle class and above could own (blue), or something only the wealthiest could own (yellow).





Note: participants who were themselves in the richest wealth tertile categorized more assets as something anyone, from the lowest socioeconomic class and above, would own, compared to participants in the poorest tertile, who placed more assets, on average, in the category that only a person in the highest socioeconomic class would own.

Supplemental Figure 2: Ownership of key water sanitation and hygiene items a) cisterns or elevated tanks and b) water drums, by wealth tertile. Tertiles are ordered from 1, the poorest tertile, to 3, the wealthiest tertile.



Supplemental table 1: Possessions included in the ECoMiD survey and items included in the asset ranking activity

Asked to all households	Asked to subset of households	Also included in the pile sort
Radio	Blender	Electricity
Non-mobile phone	Gas Stove	Generator
Microwave	Sewing Machine	Home owner
Television	Stereo	Cement walls
Refrigerator	Canoe	Cement floor
Computer	DVD Player	Metal roof
Wristwatch	Plot of Land	Tiled roof
Internet	Chainsaw	Farm
Mobile phone	Motor*	
Bicycle	Bank account	
Motorcycle	Washing Machine	
Scooter	Air conditioner	
Carriage pulled by animals	Shower	
Car or truck	Hot Plate	
Boat with an engine	Iron	
None	Oven	
	Fan	
	Video Camera	
	Exercise Machine	
	Sandwich maker	
	Electric mixer	

Supplemental Table 2a: Possession ownership among ECoMiD study households by wealth tertile. Results from the ECoMiD survey data.

BY SES	Poorest (N=174)	Middle (N=174)	Wealthiest (N=173)	Overall (N=521)
Radio				
	10 (5.7%)	34 (19.5%)	58 (33.5%)	102 (19.6%)
Landline				
	16 (9.2%)	35 (20.1%)	54 (31.2%)	105 (20.2%)
Microwave				
	0 (0%)	0 (0%)	46 (26.6%)	46 (8.8%)
TV				
	128 (73.6%)	167 (96.0%)	167 (96.5%)	462 (88.7%)
Fridge				
	93 (53.4%)	160 (92.0%)	165 (95.4%)	418 (80.2%)
Computer				
	0 (0%)	1 (0.6%)	73 (42.2%)	74 (14.2%)
Watch				
	29 (16.7%)	47 (27.0%)	60 (34.7%)	136 (26.1%)
Internet				
	2 (1.1%)	16 (9.2%)	98 (56.6%)	116 (22.3%)
Cell phone				
	28 (16.1%)	103 (59.2%)	120 (69.4%)	251 (48.2%)
Bike				
	1 (0.6%)	6 (3.4%)	33 (19.1%)	40 (7.7%)
Motorcycle				
	1 (0.6%)	5 (2.9%)	54 (31.2%)	60 (11.5%)
Scooter				
	0 (0%)	1 (0.6%)	3 (1.7%)	4 (0.8%)
Animal drawn cart				
	1 (0.6%)	0 (0%)	1 (0.6%)	2 (0.4%)
Car or truck				
	1 (0.6%)	5 (2.9%)	11 (6.4%)	17 (3.3%)
Boat with engine				
	4 (2.3%)	2 (1.1%)	2 (1.2%)	8 (1.5%)

BY SES	Poorest (N=137)	Middle (N=129)	Wealthiest (N=136)	Overall (N=402)
Blender				
	76 (55.5%)	87 (67.4%)	76 (55.9%)	239 (59.5%)
Gas stove				
	63 (46.0%)	65 (50.4%)	56 (41.2%)	184 (45.8%)
Sewing machine				
	0 (0%)	1 (0.8%)	2 (1.5%)	3 (0.7%)
Stereo				
	1 (0.7%)	0 (0%)	1 (0.7%)	2 (0.5%)
Canoe				
	2 (1.5%)	4 (3.1%)	6 (4.4%)	12 (3.0%)
DVD player				
	8 (5.8%)	5 (3.9%)	6 (4.4%)	19 (4.7%)
Plot of land				
	4 (2.9%)	12 (9.3%)	13 (9.6%)	29 (7.2%)
Chainsaw				
	1 (0.7%)	1 (0.8%)	3 (2.2%)	5 (1.2%)
Motor/generator				
	2 (1.5%)	3 (2.3%)	7 (5.1%)	12 (3.0%)
Bank account				
	13 (9.5%)	20 (15.5%)	36 (26.5%)	69 (17.2%)
Washing machine				
	51 (37.2%)	61 (47.3%)	70 (51.5%)	182 (45.3%)
AC				
	0 (0%)	0 (0%)	1 (0.7%)	1 (0.2%)
Shower				
	15 (10.9%)	21 (16.3%)	38 (27.9%)	74 (18.4%)
Iron				
	37 (27.0%)	58 (45.0%)	64 (47.1%)	159 (39.6%)
Oven				
	2 (1.5%)	3 (2.3%)	19 (14.0%)	24 (6.0%)
Fan				
	37 (27.0%)	54 (41.9%)	63 (46.3%)	154 (38.3%)
Exercise machine				
	0 (0%)	0 (0%)	1 (0.7%)	1 (0.2%)

BY SES	Poorest (N=137)	Middle (N=129)	Wealthiest (N=136)	Overall (N=402)
Sandwich maker				
	3 (2.2%)	6 (4.7%)	17 (12.5%)	26 (6.5%)

Items included in the multiple correspondence analysis shown in grey. Data on all 36 items only available for a subset (N=402) of children due to an adjustment to the survey made partway through the data collection process.

Supplemental Table 2b: Possession ownership among ECoMiD study households by remoteness. Results from the ECoMiD survey data.

BY SITE	Rural - river (N=53)	Rural - road (N=173)	Intermediate (N=163)	Urban (N=132)	Overall (N=521)	P-value for items in the MCA*
Radio						<0.001
	9 (17.0%)	14 (8.1%)	37 (22.7%)	42 (31.8%)	102 (19.6%)	
Landline						0.001
	7 (13.2%)	47 (27.2%)	22 (13.5%)	29 (22.0%)	105 (20.2%)	
Microwave						0.11
	4 (7.5%)	15 (8.7%)	9 (5.5%)	18 (13.6%)	46 (8.8%)	
TV						0.03
	49 (92.5%)	153 (88.4%)	136 (83.4%)	124 (93.9%)	462 (88.7%)	
Fridge						0.001
	41 (77.4%)	134 (77.5%)	121 (74.2%)	122 (92.4%)	418 (80.2%)	
Computer						0.001
	5 (9.4%)	12 (6.9%)	27 (16.6%)	30 (22.7%)	74 (14.2%)	
Watch						<0.001
	26 (49.1%)	56 (32.4%)	49 (30.1%)	5 (3.8%)	136 (26.1%)	
Internet						<0.001
	1 (1.9%)	25 (14.5%)	38 (23.3%)	52 (39.4%)	116 (22.3%)	
Cell phone						0.0002
	15 (28.3%)	82 (47.4%)	98 (60.1%)	56 (42.4%)	251 (48.2%)	
Bike						0.26
	2 (3.8%)	12 (6.9%)	11 (6.7%)	15 (11.4%)	40 (7.7%)	
Motorcycle						0.04
	2 (3.8%)	28 (16.2%)	19 (11.7%)	11 (8.3%)	60 (11.5%)	
Scooter						

BY SITE	Rural - river (N=53)	Rural - road (N=173)	Intermediate (N=163)	Urban (N=132)	Overall (N=521)	P-value for items in the MCA*
	0 (0%)	2 (1.2%)	1 (0.6%)	1 (0.8%)	4 (0.8%)	
Animal drawn cart						
	0 (0%)	0 (0%)	2 (1.2%)	0 (0%)	2 (0.4%)	
Car or truck						
	0 (0%)	7 (4.0%)	5 (3.1%)	5 (3.8%)	17 (3.3%)	
Boat with engine						
	8 (15.1%)	0 (0%)	0 (0%)	0 (0%)	8 (1.5%)	

	Rural - river (N=42)	Rural - road (N=143)	Intermediate (N=117)	Urban (N=100)	Overall (N=402)
Blender					
	28 (66.7%)	86 (60.1%)	60 (51.3%)	65 (65.0%)	239 (59.5%)
Gas stove					
	18 (42.9%)	70 (49.0%)	56 (47.9%)	40 (40.0%)	184 (45.8%)
Sewing machine					
	0 (0%)	1 (0.7%)	0 (0%)	2 (2.0%)	3 (0.7%)
Stereo					
	0 (0%)	0 (0%)	2 (1.7%)	0 (0%)	2 (0.5%)
Canoe					
	4 (9.5%)	3 (2.1%)	5 (4.3%)	0 (0%)	12 (3.0%)
DVD player					
	18 (42.9%)	0 (0%)	1 (0.9%)	0 (0%)	19 (4.7%)
Plot of land					
	2 (4.8%)	16 (11.2%)	11 (9.4%)	0 (0%)	29 (7.2%)

	Rural - river (N=42)	Rural - road (N=143)	Intermediate (N=117)	Urban (N=100)	Overall (N=402)
Chainsaw					
	0 (0%)	1 (0.7%)	3 (2.6%)	1 (1.0%)	5 (1.2%)
Motor/generator					
	3 (7.1%)	2 (1.4%)	6 (5.1%)	1 (1.0%)	12 (3.0%)
Bank account					
	8 (19.0%)	32 (22.4%)	26 (22.2%)	3 (3.0%)	69 (17.2%)
Washing machine					
	22 (52.4%)	70 (49.0%)	46 (39.3%)	44 (44.0%)	182 (45.3%)
AC					
	0 (0%)	0 (0%)	0 (0%)	1 (1.0%)	1 (0.2%)
Shower					
	1 (2.4%)	29 (20.3%)	18 (15.4%)	26 (26.0%)	74 (18.4%)
Iron					
	13 (31.0%)	62 (43.4%)	41 (35.0%)	43 (43.0%)	159 (39.6%)
Oven					
	0 (0%)	9 (6.3%)	7 (6.0%)	8 (8.0%)	24 (6.0%)
Fan					
	9 (21.4%)	61 (42.7%)	36 (30.8%)	48 (48.0%)	154 (38.3%)
Exercise machine					
	0 (0%)	0 (0%)	0 (0%)	1 (1.0%)	1 (0.2%)
Sandwich maker	0 (0%)	9 (6.3%)	12 (10.3%)	5 (5.0%)	26 (6.5%)

MCA = multiple correspondence analysis. Items included in the multiple correspondence analysis shown in grey. Data on all 36 items only available for a subset (N=402) of children due to an adjustment to the survey made partway through the data collection process. *P*-values from chi-squared or fisher's exact tests. Not adjusted for multiple comparisons.

Supplemental Table 3: Mean household wealth score and standard deviation (SD) by community and remoteness. Unscaled mean and SD presented in addition.

Community	Mean	Standard Deviation	Unscaled mean	Unscaled SD
Esmeraldas	0.32	1.07	0.14	0.48
Borbón	-0.02	1.06	-0.01	0.48
Rural-Road	-0.13	0.89	-0.06	0.40
Colon Eloy	0.025	0.98	0.01	0.44
Maldonado	-0.10	1.01	-0.04	0.45
Selva Alegre	-0.32	0.50	-0.14	0.22
Timbiré	-0.23	0.71	-0.10	0.32
Rural-River	-0.31	0.77	-0.14	0.34
Colon	-0.54	0.42	-0.24	0.19
San Francisco	0.16	1.42	0.07	0.64
Santo Domingo	-0.42	0.58	-0.19	0.26
Zancudo	-0.22	0.67	-0.10	0.30
Overall	0	1	0	0.45

Supplemental Table 4: Area under the receiver operating characteristic curve (AUC) values comparing the asset-based socioeconomic status score to alternate socioeconomic status proxy indicators by remoteness

AUC values comparing asset score to alternate SES proxy indicators by location					
	Overall	Urban	Intermediate	Rural - road	Rural - river
Maternal education	0.62	0.63	0.59	0.57	0.60
Housing materials	0.74	0.78	0.71	0.73	0.78
Income*	0.64	0.63	0.63	0.62	0.75
Job type*	0.67	0.73	0.62	0.69	0.98

*Extremely small total population in Rural-River communities with low variation in the income and job type indicators

Venkatraman's test for two unpaired ROC curves comparing the remoteness site-specific curves for each indicator showed no statistical difference in amount explained between sites.

Supplemental Table 5: Main reported source of drinking water among households with a piped connection by wealth tertile. Results from the ECoMiD survey data.

	Poorest (N=82)	Middle (N=94)	Wealthiest (N=128)	Overall (N=304)
Main reported source of water consumption				
Bottled water	39 (47.6%)	37 (39.4%)	72 (56.3%)	148 (48.7%)
Piped water connection	34 (41.5%)	45 (47.9%)	41 (32.0%)	120 (39.5%)
Public tap	7 (8.5%)	9 (9.6%)	11 (8.6%)	27 (8.9%)

Supplemental Table 6: Thresholds of wealth for complete household water, sanitation, and hygiene coverage by remoteness. Complete WASH coverage defined as access to at least limited or basic water and sanitation and basic hygiene in a household.

Remoteness	Wealth tertile	Complete WASH coverage
Urban	1	60%
Urban	2	65%
Urban	3	73%
Intermediate	1	41%
Intermediate	2	52%
Intermediate	3	70%
Rural - river	1	46%
Rural - river	2	56%
Rural - river	3	82%
Rural - road	1	58%
Rural - road	2	55%
Rural - road	3	74%

Supplemental Table 7a: Breakdown of the complete household water, sanitation, and hygiene indicator components by wealth. Complete WASH coverage defined as access to at least limited or basic water and sanitation and basic hygiene in a household. Results from the ECoMiD survey data.

	Poorest (N=174)	Middle (N=174)	Wealthiest (N=173)	Overall (N=521)
Basic or limited sanitation				
Yes	147 (84.5%)	160 (92.0%)	170 (98.3%)	477 (91.6%)
Missing	5 (2.9%)	2 (1.1%)	1 (0.6%)	8 (1.5%)
Basic or limited water				
Yes	168 (96.6%)	169 (97.1%)	167 (96.5%)	504 (96.7%)
Missing	2 (1.1%)	1 (0.6%)	4 (2.3%)	7 (1.3%)
Sink with soap and water				
Yes	107 (61.5%)	110 (63.2%)	133 (76.9%)	350 (67.2%)

Supplemental Table 7b Breakdown of the complete household water, sanitation, and hygiene indicator components by geography - remoteness, community, and neighborhood (where available). Complete WASH coverage defined as access to at least limited or basic water and sanitation and basic hygiene in a household. Results from the ECoMiD survey data.

	Rural - river (N=53)	Rural - road (N=173)	Intermediate (N=163)	Urban (N=132)	Overall (N=521)
Basic or limited sanitation					
Yes	37 (69.8%)	165 (95.4%)	146 (89.6%)	129 (97.7%)	477 (91.6%)
Missing	0 (0%)	2 (1.2%)	4 (2.5%)	2 (1.5%)	8 (1.5%)
Basic or limited water					
Yes	50 (94.3%)	169 (97.7%)	157 (96.3%)	128 (97.0%)	504 (96.7%)
Missing	1 (1.9%)	2 (1.2%)	0 (0%)	4 (3.0%)	7 (1.3%)
Sink with soap and water					
Yes	47 (88.7%)	114 (65.9%)	98 (60.1%)	91 (68.9%)	350 (67.2%)

	Borbón (N=163)	Colon (N=19)	Colon Eloy (N=32)	Esmeraldas (N=132)	Maldonado (N=83)	San Francisco (N=8)	Santo Domingo (N=8)	Selva Alegre (N=27)	Timbiré (N=31)	Zancudo (N=18)	Overall (N=521)
Basic or limited sanitation											
Yes	146 (89.6%)	4 (21.1%)	30 (93.8%)	129 (97.7%)	78 (94.0%)	7 (87.5%)	8 (100%)	26 (96.3%)	31 (100%)	18 (100%)	477 (91.6%)
Missing	4 (2.5%)	0 (0%)	1 (3.1%)	2 (1.5%)	1 (1.2%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	8 (1.5%)
Basic or limited water											
Yes	157 (96.3%)	18 (94.7%)	31 (96.9%)	128 (97.0%)	83 (100%)	8 (100%)	8 (100%)	25 (92.6%)	30 (96.8%)	16 (88.9%)	504 (96.7%)
Missing	0 (0%)	0 (0%)	1 (3.1%)	4 (3.0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (3.2%)	1 (5.6%)	7 (1.3%)
Sink with soap and water											
Yes	98 (60.1%)	19 (100%)	31 (96.9%)	91 (68.9%)	34 (41.0%)	6 (75.0%)	8 (100%)	22 (81.5%)	27 (87.1%)	14 (77.8%)	350 (67.2%)

BORBON

	Cayapas Arriba (N=2)	Cayapas Abajo (N=14)	Centro (N=13)	Lechugal (N=27)	Miduvi (N=4)	Parque (N=4)	Primero de Mayo (N=3)	Torres Gemelas (N=47)	Other (N=49)	Overall (N=163)
Basic or limited sanitation										
Yes	1 (50.0%)	12 (85.7%)	13 (100%)	24 (88.9%)	4 (100%)	4 (100%)	3 (100%)	43 (91.5%)	42 (85.7%)	146 (89.6%)
Missing	0 (0%)	0 (0%)	0 (0%)	1 (3.7%)	0 (0%)	0 (0%)	0 (0%)	1 (2.1%)	2 (4.1%)	4 (2.5%)
Basic or limited water										
Yes	2 (100%)	14 (100%)	13 (100%)	26 (96.3%)	4 (100%)	4 (100%)	3 (100%)	47 (100%)	44 (89.8%)	157 (96.3%)
Sink with soap and water										
Yes	1 (50.0%)	4 (28.6%)	9 (69.2%)	22 (81.5%)	3 (75.0%)	3 (75.0%)	3 (100%)	25 (53.2%)	28 (57.1%)	98 (60.1%)

	Cayapas Arriba (N=2)	Cayapas Abajo (N=14)	Centro (N=13)	Lechugal (N=27)	Miduvi (N=4)	Parque (N=4)	Primero de Mayo (N=3)	Torres Gemelas (N=47)	Other (N=49)	Overall (N=163)
Wealth tertile										
Poorest	1 (50.0%)	4 (28.6%)	3 (23.1%)	9 (33.3%)	3 (75.0%)	0 (0%)	1 (33.3%)	16 (34.0%)	22 (44.9%)	59 (36.2%)
Middle	0 (0%)	7 (50.0%)	4 (30.8%)	8 (29.6%)	1 (25.0%)	1 (25.0%)	2 (66.7%)	18 (38.3%)	13 (26.5%)	54 (33.1%)
Wealthiest	1 (50.0%)	3 (21.4%)	6 (46.2%)	10 (37.0%)	0 (0%)	3 (75.0%)	0 (0%)	13 (27.7%)	14 (28.6%)	50 (30.7%)

ESMERALDAS

	15 de Marzo (N=25)	24 de Mayo (N=3)	Aire libre alto (N=2)	Barrio las Americas (N=2)	Casa Bonita (N=7)	Codesa (N=4)	San Rafael (N=1)	Tiwinza (N=1)	Other (N=87)	Overall (N=132)
Basic or limited sanitation										
Yes	25 (100%)	3 (100%)	2 (100%)	2 (100%)	6 (85.7%)	4 (100%)	1 (100%)	1 (100%)	85 (97.7%)	129 (97.7%)
Missing	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (14.3%)	0 (0%)	0 (0%)	0 (0%)	1 (1.1%)	2 (1.5%)
Basic or limited water										
Yes	25 (100%)	3 (100%)	2 (100%)	2 (100%)	7 (100%)	4 (100%)	1 (100%)	1 (100%)	83 (95.4%)	128 (97.0%)
Missing	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	4 (4.6%)	4 (3.0%)
Sink with soap and water										
Yes	15 (60.0%)	2 (66.7%)	2 (100%)	1 (50.0%)	6 (85.7%)	4 (100%)	1 (100%)	1 (100%)	59 (67.8%)	91 (68.9%)
Wealth tertile										
Poorest	4 (16.0%)	0 (0%)	0 (0%)	1 (50.0%)	1 (14.3%)	1 (25.0%)	0 (0%)	1 (100%)	17 (19.5%)	25 (18.9%)
Middle	10 (40.0%)	1 (33.3%)	0 (0%)	0 (0%)	1 (14.3%)	1 (25.0%)	1 (100%)	0 (0%)	34 (39.1%)	48 (36.4%)
Wealthiest	11 (44.0%)	2 (66.7%)	2 (100%)	1 (50.0%)	5 (71.4%)	2 (50.0%)	0 (0%)	0 (0%)	36 (41.4%)	59 (44.7%)

Supplemental Table 8: Complete household water, sanitation, and hygiene by study community and neighborhood.
Complete WASH coverage defined as access to at least limited or basic water and sanitation and basic hygiene in a household. Results from the ECoMiD survey data.

	Borbón (N=163)	Colon (N=19)	Colon Eloy (N=32)	Esmeraldas (N=132)	Maldonado (N=83)	San Francisco (N=8)	Santo Domingo (N=8)	Selva Alegre (N=27)	Timbiré (N=31)	Zancudo (N=18)	Overall (N=521)
Household has at least limited or basic water, sanitation, and hygiene											
Yes	87 (53.4%)	4 (21.1%)	28 (87.5%)	89 (67.4%)	33 (39.8%)	6 (75.0%)	8 (100%)	20 (74.1%)	26 (83.9%)	12 (66.7%)	313 (60.1%)
Missing	0 (0%)	0 (0%)	2 (6.3%)	2 (1.5%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (3.2%)	1 (5.6%)	6 (1.2%)

BORBON

	Cayapas Arriba (N=2)	Cayapas Abajo (N=14)	Centro (N=13)	Lechugal (N=27)	Miduvi (N=4)	Parque (N=4)	Primero de Mayo (N=3)	Torres Gemelas (N=47)	Other (N=49)	Overall (N=163)
Household has at least limited or basic water, sanitation, and hygiene										
Yes	0 (0%)	2 (14.3%)	9 (69.2%)	20 (74.1%)	3 (75.0%)	3 (75.0%)	3 (100%)	24 (51.1%)	23 (46.9%)	87 (53.4%)

ESMERALDAS

	15 de Marzo (N=25)	24 de Mayo (N=3)	Aire libre alto (N=2)	Barrio las Americas (N=2)	Casa Bonita (N=7)	Codesa (N=4)	San Rafael (N=1)	Tiwinza (N=1)	Other (N=87)	Overall (N=132)
Household has at least limited or basic water, sanitation, and hygiene										
Yes	15 (60.0%)	2 (66.7%)	2 (100%)	1 (50.0%)	6 (85.7%)	4 (100%)	1 (100%)	1 (100%)	57 (65.5%)	89 (67.4%)
Missing	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (2.3%)	2 (1.5%)

Supplemental Table 9: Ownership of key water, sanitation, and hygiene items by a) wealth tertile b) remoteness and c) stratified by wealth tertile and community. Key items defined in qualitative interviews and freelists. Results from the ECoMiD survey data.

Supplemental Table 9a: Ownership of key WASH items by wealth tertile

	Poorest (N=174)	Middle (N=174)	Wealthiest (N=173)	Overall (N=521)
Cistern or elevated tank				
Owned	7 (4.0%)	12 (6.9%)	25 (14.5%)	44 (8.4%)
Cistern				
Owned	4 (2.3%)	8 (4.6%)	19 (11.0%)	31 (6.0%)
Drums				
Owned	95 (54.6%)	75 (43.1%)	54 (31.2%)	224 (43.0%)
Tank inside				
Owned	75 (43.1%)	88 (50.6%)	93 (53.8%)	256 (49.1%)
Tank outside				
Owned	41 (23.6%)	42 (24.1%)	52 (30.1%)	135 (25.9%)

Supplemental Table 9b: Ownership of key water, sanitation, and hygiene items by remoteness

	Rural - river (N=53)	Rural - road (N=173)	Intermediate (N=163)	Urban (N=132)	Overall (N=521)
Cistern or elevated tank					
Owned	2 (3.8%)	5 (2.9%)	16 (9.8%)	21 (15.9%)	44 (8.4%)
Cistern					
Owned	0 (0%)	3 (1.7%)	8 (4.9%)	20 (15.2%)	31 (6.0%)
Drums					
Owned	49 (92.5%)	92 (53.2%)	61 (37.4%)	22 (16.7%)	224 (43.0%)
Tank inside					
Owned	26 (49.1%)	79 (45.7%)	83 (50.9%)	68 (51.5%)	256 (49.1%)
Tank outside					
Owned	24 (45.3%)	37 (21.4%)	48 (29.4%)	26 (19.7%)	135 (25.9%)

Supplemental Table 9c:

Proportion of cistern and drum ownership stratified by wealth tertile and community

Community	Wealth	Cistern	Drum
Borbón	1	0%	48%
Borbón	2	4%	43%
Borbón	3	12%	20%
Colon	1	0%	91%
Colon	2	0%	83%
Colon	3	0%	50%
Colon Eloy	1	0%	40%
Colon Eloy	2	0%	38%
Colon Eloy	3	7%	43%
Esmeraldas	1	8%	24%
Esmeraldas	2	13%	19%
Esmeraldas	3	20%	12%
Maldonado	1	6%	67%
Maldonado	2	0%	65%
Maldonado	3	0%	67%
San Francisco	1	0%	100%
San Francisco	2	0%	50%
San Francisco	3	0%	100%
Santo Domingo	1	0%	100%
Santo Domingo	2	0%	100%
Santo Domingo	3	0%	100%
Selva Alegre	1	0%	38%
Selva Alegre	2	0%	31%
Selva Alegre	3	0%	17%
Timbiré	1	0%	54%
Timbiré	2	0%	56%
Timbiré	3	0%	44%
Zancudo	1	0%	100%
Zancudo	2	0%	100%
Zancudo	3	0%	100%

SUPPLEMENTAL METHODS

Interview Guide

Gracias por su participación en esta actividad. El propósito de este ejercicio es entender más sobre sus opiniones – no hay respuestas correctas, ni incorrectas. Estoy aquí para escuchar y aprender más sobre usted y su familia, y espero poder utilizar lo que aprendo para mejorar proyectos de salud público en comunidades como esta. La entrevista durara más o menos una hora. *[Hacer el proceso de consentimiento con la forma oficial, pedir permiso para grabar el audio]*

PARTE 1: LOS BIENES/LAS POSESIONES

Empezamos con una actividad en que voy a pedir que usted haga una lista de objetos. Puedes nombrar a todos los objetos que piense usted, sin límites.

- Por favor, dígame cuales son las cosas/bienes/posesiones **materiales** más importantes que tiene su familia/su casa. *[LISTA – por favor, registre las posesiones en el orden mencionado]*
    - *[¿Puede pensar en alguna otra cosa? ¿Mira alrededor de su casa, su patio, hay alguna otra cosa que quiere añadir a la lista? ¿Puede señalar o muéstrame alguna otra costa que debemos incluir en la lista? ¿Puede pensar en alguna otra cosa parecida a XXXX para incluir en la lista?]*
    - ¿Porque eligió estas cosas? ¿Porque son importantes a su familia?
- Imagínese una familia rica en su comunidad. ¿Qué tiene esa familia/casa?
    - *[¿Puede pensar en alguna otra cosa? ¿Que estaría en su casa/hogar? ¿Su patio? ¿Qué comprarían ellos? ¿Qué harían ellos?]*
    - ¿Hay algo que ellos pueden hacer, que usted y su familia no puedan?
- ¿Hay cosas que sienta usted y su familia que no puedan hacer por falta de dinero?
- ¿Hay cosas que son Importantes para usted y su familia en las que no pueden gastar dinero en este momento, pero le gustaría hacer?
    - Por ejemplo, ¿viajar, su salud, educación, actividades culturales, tiempo con la familia?
- Si usted tuviera $1,000 dólares para gastar (para usted/su familia/su casa), ¿cómo lo gastaría? ¿Porque?

Sortea de pilas 1: ¿Cuáles posesiones son las más importantes como señales de la riqueza de una familia? Por favor, ordena/clasifique estas tarjetas en **grupos de lo que tendría una casa de clase alta, una casa de clase media, y una casa de clase baja.** No hay respuestas correctas ni incorrectas, estoy muy interesada en que piensa usted.

Usted puede hacer tantas pilas/categorías/montones como quiera, pero no pueda poner todas las tarjetas juntas en una sola pila/montón. Por ejemplo, ponga cosas que indica/significa que una casa es de clase alta juntos. ¿Cómo sabe que la casa tiene mucho dinero? Si parece que falta unas cosas importantes, podemos añadir tarjetas. *[si la participante ha mencionado unas cosas nuevas en la actividad de lista, añade tarjetas con estas cosas al sorteo].*

Tarjetas:

Un Radio	Un Reproductor de DVD
Un Teléfono no móvil	Un Solar

Una Microonda	Una Motosierra
Un Televisor	Un Motor
Un Refrigerador/nevera	Una Cuenta bancaria
Una Computadora	Una Lavadora
Un Reloj de pulsera	Aire acondicionado
El Internet	Una ducha
Un Teléfono móvil	Un calientaplatos
Una Bicicleta	Una plancha
Una Motocicleta	Un horno
Una Pasola/Scooter	Un ventilador
Un Carro tirado por animales	Una cámara de video/videocámara
Un Coche o un camión	Un aparato de ejercicio
Un Barco con un motor	Una sandwichera
Una Licuadora	Una batidora eléctrica
Una Estufa de gas	Una casa (dueño)
Una Machina de coser	La electricidad / la energía
Un Estereo	Piso de cemento
Una Canoa	Ganado/animales de la hacienda
Paredes de cemento	
Techo de metal	
Techo tejada	

- ¿Es importante el número total de las cosas que tiene la familia? ¿Para cuales posesiones?
- ¿Si solo podría elegir **dos** de las tarjetas para representar cada grupo, cuáles serían?
- ¿Cuáles posesiones son lo más importantes a tener en su casa, específicamente, en su opinión? ¿Porque?
- Por favor, describe la casa de clase alta ¿Qué cosas usted ha incluido? ¿Porque? ¿Cuáles son los más importantes?
- Por favor, describe la casa de clase medio. ¿Qué cosas usted ha incluido? ¿Porque? ¿Cuáles son los más importantes?
- Por favor, describe la casa de clase baja. ¿Qué cosas usted ha incluido? ¿Porque? ¿Cuáles son los más importantes?

[Después de completar la actividad, registra el "nombre" de cada pila y los números de las tarjetas en la pila]

PART 2: WASH

En esta parte de la conversación, quiero aprender más sobre como utilizan varias cosas en su casa y en su vida diaria y cuales cosas son lo más importantes. En particular, estoy interesada en cómo la gente en su comunidad y usted obtengan agua para beber, como obtengan agua para uso en la casa/para oficios, y como mantienen una casa limpia e higiénica, incluso de como manejan las heces de la familia/sus animales. Primero voy a pedir que haga tres listas de objetos. Son todos parecidos, pero cada lista tiene un enfoque/tema un poco diferente.

- Por favor, dígame cuales son las cosas más importantes que tiene su familia/una casa en su comunidad para tener el agua para consumo/para beber que necesitan. *[LISTA – por favor, registre las posesiones en el orden mencionado]*
    - *[¿Puede pensar en alguna otra cosa que utilizan? ¿Puede mirar en su cocina, su baño, o su patio, y pensar en que tipos de objetos utilizan allí? ¿Puede pensar en alguna cosa parecida a XXXX para incluir en la lista?]*
    - ¿Me puede explicar porque has pensado en estas cosas?
    - ¿Hay algunos en la lista que usted no tenga? ¿Porque no ha comprado o construido XXX cosa?
    - ¿Las cosas importantes cambian entre la temporada de lluvia y estación seca, con inundaciones, o con sequias?
- Por favor, dígame cuales son las cosas más importantes que tiene su familia/ una casa en su comunidad para tener el agua domestica/para oficios que necesitan. *[LISTA – por favor, registre las posesiones en el orden mencionado]*
    - *[¿Puede mirar en su cocina, su baño, o su patio, y pensar en que tipos de objetos utilizan allí? ¿Puede pensar en alguna cosa parecida a XXXX para incluir en la lista?]*
    - ¿Me puede explicar porque has pensado en estas cosas?
    - ¿Hay algunos en la lista que usted no tenga? ¿Porque no ha comprado o construido XXX cosa?
    - ¿Las cosas importantes cambian entre la temporada de lluvia y estación seca, con inundaciones, o con sequias?
- Por favor, dígame cuales son las cosas más importantes que tiene su familia/ una casa en su comunidad para mantener una casa limpia e higiénica - incluso el manejo de las heces de las personas, los niños, y los animales. *[LISTA – por favor, registre las posesiones en el orden mencionado]*
    - *[¿Puede pensar en alguna otra cosa que utilizan? ¿Puede mirar en su cocina, su baño, o su patio, y pensar en que tipos de objetos utilizan allí? ¿Puede pensar en alguna cosa parecida a XXXX para incluir en la lista?]*
    - ¿Me puede explicar porque has pensado en estas cosas?
    - ¿Hay algunos en la lista que usted no tenga? ¿Porque no ha comprado o construido XXX cosa?
    - ¿Las cosas importantes cambian entre la temporada de lluvia y estación seca, con inundaciones, o con sequias?
- Imagínese una familia rica en su comunidad. ¿Qué tiene esa familia?
    - ¿Que tienen para obtener el agua para consumir que necesitan? ¿Hay diferencias para ellos entre la temporada de lluvia y estación seca, con inundaciones, o con sequias?
    - ¿Que tienen para mantener una casa limpia e higiénica? - Incluso el manejo de las heces de las personas, los niños, y los animales.

- ¿Cuáles son las diferencias más importantes entre como una casa de clase alta y uno de clase baja manejan estas cosas?

Sortea de pilas 2: **Por favor, ordenar estas tarjetas en el orden de la prioridad de tenerles en su casa para ayudarle tener agua suficiente a beber, para sus tareas/oficios, y para mantener una casa limpia/higiénica, si podría añadirles horita sin costo.** ¿Por ejemplo, si usted podría añadirles, construirles, o tenerles en su casa, cuales quería poner primero? Si parece que falta unas cosas importantes, podemos añadir tarjetas.
ALTERNATIVA: Pregunta abierta: **Cuales cosas usted considera prioridades a poner en su casa para ayudarle tener agua suficiente a beber, para sus tareas/oficios, y para mantener una casa limpia/higiénica, ¿si podría añadirles horita sin costo?** ¿Por ejemplo, si usted podría añadirles, construirles, o tenerles en su casa ahora, cuales quería poner primero?

- ¿Si usted tenía acceso consistente a agua de grifa, hay otras cosas que serían prioridades? ¿Cuales? ¿Porque?
- ¿Hay cosas en las tarjetas que quieres tener? ¿Porque?
  - ¿Que no quieres tener por razón de la falta de agua?
- Cuales cosas son las más caras/ difícil obtener? Y los más baratos/fáciles de obtener?

Tarjetas:

Pozo con tubería/protegido	Motobomba
Manantial protegido	Agua guardada y cubierto
Agua superficial - río	Cisterna
Agua potable	Pomas
Grifo público	Tanque /tambor
Carro-tanque pequeño/tambor o Camión cisterna	Agua tratado con cloro
Agua lluvia	Agua tratado con abate/abate
Agua embotellada	Filtro de agua
Acceso a agua dentro del hogar	Inodoro que descarga al sistema de alcantarillado o tanque séptico
Acceso a agua de un vecino	Letrina de pozo mejorada y ventilada
Un Fregadero/Lavamanos	Panales
Agua de buen color	Piso del baño de cemento
Agua de buen sabor	La letrina o inodoro adentro de la casa
Acceso consistente al agua	Acceso a una letrina o un inodoro no compartida
Agua sin contaminación	Acceso a una letrina o un inodoro de un vecino

Una lavadora	Jabón en la casa
Una fregona/escoba	Ducha en la casa
Un mostrador de cocina que puede limpiar	Una refrigeradora/nevera

- ¿Si usted tenía acceso consistente a agua de grifa, hay otras cosas que serían prioridades? ¿Cuales? ¿Por qué?
- ¿Hay cosas en las tarjetas que no quieres tener? ¿Por qué?
    - ¿Que no quieres tener por razón de la falta de agua?
- ¿Porque son tan importantes las cosas que son sus prioridades? ¿Que facilitan? ¿Sin estos, que no puede hacer?
- ¿Por qué no es importante tener XXX (ejemplo de una cosa no elegida como prioridad)? ¿Si ninguna de esas cosas es importante a tener, cuales cosas serían importantes?
- ¿Hay algunas cosas que no funcionan o no valen la pena tener si no tienen otra cosa para facilitar su uso?
- ¿Cuáles cosas usted quiere tener en su propia casa? ¿Hay otras cosas no en las tarjetas que le gustaría tener en la casa?
- Cuales cosas son las más caras/ difícil obtener? Y los más baratos/fáciles de obtener?
- Cuáles serían las diferencias más significantes/importantes entre una casa de clase alta y una casa de clase baja, en términos de tener y utilizar estas cosas?

[Después de completar la actividad, registra el "nombre" de cada pila y los números de las tarjetas en la pila]

<u>Preguntas abiertas</u>

- ¿Qué piensa usted es la parte más difícil de manejar/gestionar las necesidades de su y su familia de agua? ¿Qué parte es lo más fácil?
    - ¿Que ayudara a usted a tener el agua que necesita?
    - ¿Hay cosas en que no gasta dinero en este momento, pero que piensa que son importante para sus necesidades y compraría si podría?
    - ¿Cuáles cosas relacionadas al agua son compras diarias y cuales son compras más grandes/para largo plazo?
    - ¿Cuáles cosas puede construir que facilitaran el proceso?
    - ¿Cuáles actividades ayuda con este proceso/son necesarios que haga? ¿Cuáles oficios están relacionados?
- ¿Qué piensa usted es la parte más difícil de manejar/gestionar las necesidades de su y su familia de mantener la casa higiénica, incluso el manejo de heces? ¿Qué parte es lo más fácil?
    - ¿Qué tipo de inodoro tiene? ¿Dónde dispone de los contenidos? ¿Hay un sistema en la comunidad para tratar los desechos? ¿Cómo funciona cuando no hay agua?
    - ¿Que ayudara a usted a mantener una casa limpia, incluso el manejo de heces?
    - ¿Hay cosas en que no gasta dinero en este momento, pero que piensa que son importante para sus necesidades y compraría si podría?
    - ¿Cuáles cosas relacionadas al manejo de heces son compras diarias y cuales son compras más grandes/para largo plazo?
    - ¿Cuáles cosas puede construir que facilitaran el proceso?

    - ¿Cuáles actividades ayuda con este proceso/son necesarios que haga? ¿Cuáles oficios están relacionados?
- Si usted tuviera $1,000 dólares para gastar (para usted/su familia/casa) pero solo podría gastarlo en cosas que facilitan el proceso de obtener agua potable/de consumo, agua doméstica, en la maneja los desechos, y el mantenimiento de una casa/familia higiénica, ¿cómo lo gastaría? ¿Por qué?
- ¿Para comprar o construir una cisterna o un baño/inodoro nuevo, cuánto dinero necesitara tener disponible? ¿Porque o porque no quiere comprar o construir ese tipo de cosas?
- Siente que la comunidad o el lugar en que usted y su familia viven haga una diferencia en su habilidad de obtener agua potable/de consumo o agua doméstica o mantener de una casa higiénica, incluso el manejo de heces?
    - ¿Tiene un sistema alcantarillado en su comunidad? ¿Cómo funciona?
    - ¿Cómo si o cómo no? ¿Es más fácil o más difícil para madres en otras comunidades para obtener esas cosas? ¿Por qué?
    - ¿Qué le gustaría tener en su comunidad que no tiene ahora?
    - ¿Qué tiene una comunidad “ideal”?
- ¿Qué hace usted para evitar tener diarrea/evitar que sus niños y su familia tienen diarrea?
    - ¿Depende en cosas que puede comprar, o cuánto dinero tiene, o dónde vives?
    - ¿Algunas de las cosas de las actividades de los dos sorteos son importantes?
    - ¿Qué hacen madres en otras comunidades para evitar tener diarrea?
- ¿Qué hace usted para evitar el dengue/evitar que sus niños y su familia contagie del dengue?
    - ¿Depende en cosas que puede comprar, o cuánto dinero tiene, o dónde vives?
    - ¿Algunas de las cosas de las actividades de los dos sorteos son importantes?
    - ¿Qué hacen madres en otras comunidades para evitar tener el dengue?

Original untranslated versions of quotes presented in the manuscript

Results, in order of appearance

Yo puedo tener una pazola pero no puedo tener una casa por vivir con mi mamá, aja… la, casa que es más importante para mí como prioridad para mí es más importante pero puede que para otras personas su prioridad sea su pazola, entonces usted va a invertir para lo que usted sea conveniente. **HH 3124**

En la clase baja tienen sus muebles pequeñito su, su cocina pequeña, en cambio en la media tienen sus cosas grande, juego de comedor grande, sus muebles grande buen televisor, en cambio acá uno pequeñito nomás ja, ja, ja…..ya como más acá unos más pequeñito tiene. **HH 2237**

No, ja, ja, ja no casi no, pero me imagino que es en la alta, si porque.. imagino que debe ser en la alta. **HH 2414**

Table 1

La cocina para cocinarles, ya, el televisor para que se entretenga, la lavadora para lavar su ropa, congelador para vender mis bolo….hielo, así, le nevera pa guardarle su comida, toma agua helada, la carpa que duerma….la licuadora pa hacerle su jugo de melón. **HH 2331**

Lo más importante mis hijo, la cocina para cocinar los alimentos, la camita en que dormir… su nevera para aunque mantener sus cosas a ellos saludables… Mi casita mía para mis hijos… porque estamos en lo ajeno nosotros, sería bueno entonces, una casita propia. **HH 1216**

Si tendría yo hacer mi casa para estar con mis hija y ayudarlas pa que sigan su estudio, que sean alguien en la vida. **HH 3207**

Que compraría….que voy a comprar con mil dólares además de comida nada más ja, ,ja, ja. **HH 4012**

Para mi vida lo más importante la salud, tener alimento para los niño. **HH 11**

Lo importante ahí en lo material tanto no, es como en lo….en lo, cómo es, para el estudio de ellos y para sustentarla a ella en la comida, ya, así sea que viva por, o sea que se vea mi casa un poco pero que mis hijos no aguanten hambre para mí, ya. **HH 4014**

Table 2

Me imagino que aquí la mayoría bebe su agua potable porque no somos todos que compramos el agua la mayoría bebe su agua yo no, yo esa agua a mí no me pasa aquí no tomamos agua pero menos que la mayoría que no tiene como es está comprando agua toman agua de llave, porque hay personas que si toman agua, si… van a enfermar con el tiempo se enferman el estómago pues….es que no es buena agua. **HH3207**

Yo creo que aún se usan, de eso que hacían nomás hueco y ponían ahí de madera, hay gentes que aún lo usan no hay muchas pero hay dos que tres, también eso de, de lo que vinieron del programa del MIDUVI también ayudó mucho porque este¡: ya vinieron completas lo único que creo que no tienen cerámica unas, no entregaron con cerámica pero otros ya la han adecuado pero tienen su baño, el sistema de agua no hay porque eso no es que es algo fácil aquí. **HH 3124**

Table 3

A veces todos como que estamos como contento como que el agua está, como le explico el agua que nos llega está bien, o sea todo está bien pero al fin y al cabo no, porque es un tema muy importante de tratar cuando hablamos del agua porque por ejemplo hay clase medias y de que no pueden, como los que no podemos y tenemos que comprar el agua, y la clase muy baja tienen que ingerir esa agua porque les llega, no les ha toca otra porque no tienen como comprar ya yo pue cuando me alcanza compro pero hay personas que no y sería muy importante de que mejoren el agua para que todos podamos tanto como clase media, ja, ja, ja los pueblos podamos ingerir una buena calidad de agua para que pueda, o sea así mismo se puedan evitar las enfermedades porque es una forma de proteger también ja, ja, ja. **HH 2414**

Details on the SES indicators in the survey data

Possession data were initially collected on ownership of 15 household possessions determined based on other established surveys (e.g., DHS Wealth Index, Simple Poverty Scorecard, National Ecuadorian surveys such as ENSANUT)[153–155] and on past work in the research area[92,156–158] (**Supplemental Table 1**). This survey was applied during the initial pregnancy visit and reapplied if a household moved during the study. At a later stage, the possession survey was expanded to 36 household possessions, but these data were only available for a subset of households. The full possession list was included in the qualitative data activities (e.g., ranking).

Maternal education was first categorized as primary (6 years) or less, lower secondary, upper secondary (12 years), and post-secondary or greater. The binary version considered upper secondary and post-secondary or greater as "greater education" compared to lower secondary and below as "less education."

Income was self-reported by mothers as average monthly income for the household. The binary version considered income of over the median income value in the dataset of $300/month to be "high" vs <$300 as low.

Maternal job type included don't work, domestic work in the home, domestic work in someone else's home, student, work with children, cut trees, raise animals, crafts, gold mining, fisherwoman, work with food/cook, government, business, teacher, health worker, physical work, agriculture on owned land, agriculture on someone else's land, palm oil plantation worker, day laborer, pension.

The binary version of maternal job categorized jobs that typically take place outside the home as "professional" and considered other types of jobs not to represent formal employment. This was reflected as important in our qualitative feedback as well:

> *"There isn't stable work here, we don't have salaries, where the money comes every month and you can separate it out, one part for food, one for the children…. No, we live day to day, looking for enough to eat, or to pay for something." [6014]*

A score for **building materials** ranging from 0-6 was calculated based on observed wall and roof materials (see below). The binary version considered scores of five or six to be "higher quality and durability" compared to scores of four or below.

Building materials

A building materials score was created based on an approach originally developed by Arias & De Vos 1996[135] and adapted in prior EcoDESS publications.[157] Arias and De Vos suggest that building scores may overcome some limitations of other SES measures, such as occupation, that may not capture differences in sex and age well, and that people may value housing materials similarly in Latin America. This point was reflected in some of our qualitative work:

> *"A low-class person has a house made out of sticks, a dirt floor, a thatched roof, or a roof of plastic, and they have to find a way to get bread to eat. In the middle class a person has a cement house, not a fancy one… a small job. An upper-class person has a nice house, they can move around in their own vehicles, they have air conditioning, they have everything in their house – they don't have to leave like those in the middle and lower class, to get the things they need." [1149]*

"In the lower class you do what you can, you can build a single-story house. A household that has money sometimes has a house with two or three floors, prettier than the [house] of a lower-class person." [2235]

"I want to buy a plot of land to build my own house, because we are in an invasion and it isn't our own house" [2235]

Arias and De Vos suggest including electricity, water, and sewage in their housing scale, however, in ECoMiD electricity access was near universal (outages aside) and water and sanitation are major focuses of our analysis and thus cannot be included in a composite housing indicator. Because floor type is also an exposure for enteric infection, we also excluded it from our composite housing score.

Categorization of roof and wall types was standardized as best as possible in alignment with Arias and De Vos and past ECoMiD work, however as the authors acknowledge in their original paper, categorization is subject to human error or misclassification due to differences in local language to identify material types. Overall, the approach rewards quality and durability of material with higher scores, with the lowest quality and least durable materials assigned a zero. Unit differences are not necessarily equal in space (e.g., wood vs brick) and so the scores are ordinal variables rather than interval, and the aggregate score is more relevant for interpretation.

Cronbach's Alpha was used to assess internal consistency. (=0.8 looking at correlation of scores roof, scored wall, and housing score composite)

UPDATED House and Roof Material Scores Used in Wealth Score

Roof Material	***Wall Material***	***Score***
None, Plastic	Metallic sheet, refuse	0
Straw, Palm	Palm, Reed	1
Wooden boards, Zinc	Wood, plywood	2
Cement, Ceramic	Cement, Stone, Brick	3

Wealth Score = Roof Score + Wall Score; wealth scores range from 0-6

Receiver under the operator curves

We ran four individual logistic regression models using the binary versions of each of the four alternate SES proxies (maternal education, building materials, income, and job type) as the outcome and the asset-based SES indicator as the predictor, modelled separately across the four remoteness locations (Urban, Intermediate, rural-road, and rural-river) to assess if the asset-based SES indicator was functioning similarly in each of the four sites, using receiver operating characteristic (ROC) curves. We expected that if the indicator was functioning similarly, it would have similar area under the curve (AUC) values in each of the four remoteness sites when compared with other indicators we similarly expect to be proxies for wealth. Venkatraman's test for two unpaired ROC curves was used to assess statistical differences between curves.

Chapter 4: Estimating the effects of household water, sanitation, and hygiene and household wealth on child health in northwest Ecuador

Authors to be added

ABSTRACT

Introduction: Household water, sanitation, and hygiene (WASH), and wealth are both important determinants of child health, but more information is needed to disentangle their mutual and individual effects. We explore how WASH, wealth, and season impact enteric infection and child growth using cohort data from northwest Ecuador.

Methods: We focus on three health outcomes among children participating in the ECoMiD cohort study: enteric infections at 6 months (defined as high (≥4) enteric co-infection ('HiC') and absence of infection; n=324), and attained growth at two years (length-for-age Z-score [LAZ] and stunting; n=295). We assess if these child health outcomes were distributed inequitably across our study population, then assess if coverage with complete WASH (at least basic or limited water and sanitation and basic hygiene) and household wealth were associated with these outcomes using generalized linear and logistic regression models. Finally, we stratify our data to explore if prevalence of any infection, HiC, or stunting vary by WASH and wealth or by WASH and season.

Results: We found a marginally higher burden of HiC and stunting among the poorest households in our study, but no clear pattern for no infections. Complete household WASH was associated with lower odds of HiC (aOR 0.56 [0.32-0.97]), but we didn't find evidence of an association with lack of infection, LAZ, or stunting. We didn't find evidence that wealth was associated with enteric infection detection or HiC. Higher wealth was associated with higher LAZ (mean difference of 0.20 [0.03-0.38]), but we didn't find evidence of an association with reduced odds of stunting. Prevalence of HiC was higher in the dry compared to the rainy season in households *without* complete WASH, while prevalence was similar between seasons in households with complete WASH. Conversely, prevalence of no infection was higher in the dry vs rainy seasons in households *with* complete WASH, and similar between households in the rainy season.

Discussion: Our results demonstrate that having complete WASH can protect against high rates of childhood enteric coinfection, and suggest that household WASH can mitigate seasonal variation in infection. Wealth, but not WASH, impacted child growth, but neither WASH nor wealth had an impact on stunting, which is consistent with other studies. Data on enteric coinfections provides insight into pathways by which WASH, wealth, and season interact.

INTRODUCTION

Lack of access to water, sanitation, and hygiene (WASH) is increasingly recognized as a result of interconnected inequities.[149,150] The resulting health burden primarily impacts children in the poorest and otherwise vulnerable communities: more than 440,000 children under five die as a result of diarrheal diseases every year, primarily in low-resource settings.[6,7] A 2023 analysis estimated that approximately 1.4 million all-age deaths and 74 million disability-adjusted life years could have been prevented in 2019 with sufficient access to safe WASH.[5] Repeated infection with the enteric pathogens responsible for this disease burden also has downstream effects on nutrition and child growth, which can have long-term negative consequences for neurological development.[159–161] Addressing these disease burdens and their determinants is a vital component of achieving health equity.

Despite decades of progress made on improving access to WASH globally, important gaps in coverage remain, particularly in low resource settings.[162] Yet lack of access is not the only challenge: recent large-scale interventions that increased access to WASH did not generate the expected levels of improvements to the WASH-related health burden.[36–39] It has been posited that the interventions were not transformational enough to create the conditions that would have an impact on diarrheal diseases and stunting, the primary outcomes measured.[163,164] 'Transformative WASH' would entail dramatically reducing fecal contamination – human and animal – in the household environment.[164]

Public water supply and sanitation infrastructure at the community level is one piece of the transformative WASH vision.[165] But access to and quality of public infrastructure is highly variable. Even in communities that have WASH infrastructure, households face barriers to accessing consistent, quality services, including infrastructural variability and unaffordability.[64] It is possible that factors that intersect with WASH to modify household conditions and child

health, such as poverty, may also need to be addressed in order to achieve targeted child health gains.

At the household level, poorer households are less likely to have access to WASH,[143] even if WASH infrastructure exists in their community.[64] Our own work suggests that household wealth can help households to access WASH,[166] and several other studies have found that the potential health benefits of increasing access to WASH are highest among the poorest segments of the population,[86] suggesting that expanded WASH access can help offset income-related health disparities.[118] It is unclear to what extent household wealth and household WASH can interact to impact the stubbornly high child health burdens of enteric infection and stunting.

Other conditions may also impact the extent to which a household can or must utilize WASH resources available at the community level. For instance, extreme climate events like flooding and drought may overwhelm public infrastructure or increase water scarcity, increasing WASH-related household expenditures related to coping with water insecurity.[92] Incidence of enteric infections and diarrhea are known to be highly seasonal,[167–169] and recent research has found that household WASH interventions may be more protective during specific seasons,[86,87,170] but more evidence is needed on the ways in which household WASH and season interact to affect child health.

In this study, we explore the relationships between household WASH and household wealth and child health using data on enteric infections in children at six months and stunting at two years of age collected as a part of the ECoMiD cohort in ten communities in northwest Ecuador spanning a range of infrastructural and remoteness contexts. We first investigate if our child health outcomes of interest—no enteric infections, high levels of enteric co-infection (HiC), length-for-age z-score (LAZ), and stunting—are distributed inequitably in our study population. We then assess if household WASH or household wealth are associated with these health outcomes. Finally, we examine how prevalence of enteric infection and stunting varies under

different household WASH conditions across wealth contexts and seasons. Understanding how poverty, season, and WASH intersect to impact child health is crucial to devise and improve WASH interventions to reduce the WASH-related disease burden for all.

METHODS

Study population & overview

In this study we utilized data collected as a part of the ECoMiD (in Spanish, ('*Enteropatógenos, Crecimiento, Microbioma, y Diarrea*') prospective birth cohort study in Ecuador[171] to explore the relationship of household WASH, household wealth, and season with child enteric infection at six months and stunting at two years. ECoMiD enrolled 521 mother-child dyads across an urban-rural gradient in the province of Esmeraldas, including the city of Esmeraldas (pop ~150,000), referred to here as the urban site; the town of Borbón (pop ~4,500), a commercial center referred to as the intermediate site; and eight smaller rural towns (pops 200-1,000), some primarily accessible only by river and others connected to roads, referred to as 'rural-river' and 'rural-road' communities, respectively. The province of Esmeraldas is primarily Afro-Ecuadorian.[56,57,58]

Data collection

Details on consent processes, eligibility criteria, enrollment and study protocols have been published elsewhere.[172] In brief, mothers were enrolled late in pregnancy, and study visits were conducted a total of ten times per household, at 37 weeks of pregnancy, 1 week after birth, and at 3, 6, 9, 12, 15, 18, 21, and 24 months of child-age. Surveys and spot checks were conducted at each visit and data collected on numerous variables such as household WASH characteristics, socioeconomic status, maternal education, and vaccine status. Environmental and biological samples, including water, blood, and stool, were also collected at multiple time points.

Outcome variables

Enteric infection: Stool samples were collected from children at six months of age in sterile containers and transported to the field office for aliquoting. Aliquots were transported to the

Universidad San Francisco de Quito (USFQ) for nucleic acid extraction (QIAamp Fast DNA Stool Mini Kit (QIAGEN, Germantown, MD)) and shipped to the University of Washington (UW) for molecular analysis.[146] A cold chain was maintained throughout all transport and storage steps. The field team aimed to collect samples at least +/- 21 days from the 6-month birthday, but some sample collection occurred outside of this window, so the enteric data analysis can be considered to include a slightly broader age range. We controlled for age in days in our models (see below). Since 2019, 521 mother-child dyads have been enrolled in ECoMiD, and enteric infection data was planned to be analyzed for 472 children. Of these, we excluded households that had incomplete data due to the pause in activities during the COVID-19 shutdown (81), that withdrew from the study (6), refused to provide a sample (3), moved away (20), were unavailable to be contacted (18), had a child that passed away (4), or had field or lab errors (14), for a final total of 324 samples included in the present analysis. Prior analysis of the missing data indicated that households excluded from the analysis were not substantially different than those included across key variables.[146]

TaqMan Array Cards (TAC) were used to analyze the extracted total nucleic acids for gene targets for a range of enteric infections, including bacterial, viral, and parasitic pathogens. The analysis process has been described in detail elsewhere.[146] Using the results of the TAC analysis, we created a variable of the sum total of infections in a given child of any type, excluding SARS-CoV-2. In addition, we wanted to focus on children with the highest burden of enteric infection, as these children represent the greatest burden of disease and vulnerability in our population. We created binary variables of no infection and of high enteric co-infection (HiC), defined as four or more co-infections in a single child, to capture high intensity infections.

Growth: Anthropometry data, including length, weight, and head circumference, were collected at two years of age by trained members of the field team. This study utilized data on attained growth at 2 years.

Length-for-age (LAZ), weight-for-length (WLZ), and weight-for-age (WAZ) scores were created based on WHO Growth Standards.[173] Stunting, wasting, and underweight were calculated as binary indicators defined by having Z-scores < -2.

Exposure variables

WASH: Based on prior work with household WASH data in the cohort where we found very limited variation in access to safe water and, to a lesser extent, sanitation in the study population, we used a binary indicator of household WASH access based on having "complete" household WASH or not. We defined complete access as access to at least basic or limited water (according to JMP access definitions)[144], basic or limited sanitation, and basic hygiene in the household.[166] WASH access was assessed during the six-month visit. If data were unavailable at the six-month visit, we backfilled using the pregnancy visit or later study visits.

Wealth: We developed a socioeconomic status (SES) variable informed by qualitative work within our study population, using asset ownership data collected on 11 household possessions for each household.[166] We utilized multiple correspondence analysis to generate a household wealth score from these assets and scaled the score to have mean 0 and standard deviation 1 for analysis as a continuous variable. We also categorized households into wealth tertiles based on household wealth score. The development of this variable has been described in detail elsewhere.[166] Asset data were collected at the pregnancy study visit and updated only in the event that a household moved. For the inequality analyses, we also created a ranked wealth variable, where each individual was assigned a rank based on their household wealth score, from lowest to highest.

Season: Season was defined as the season in which a particular stool sample was collected (rainy or dry). Season was only utilized in analyses related to enteric infection.

Covariates

We utilized additional survey data for potential confounders between WASH or wealth and a) enteric infection and b) growth. For enteric infection, these included maternal education (years), maternal ethnicity (Afro Ecuadorian or not), child sex, history of breastfeeding in the 14 days before the study visit (exclusive/predominant vs partial/weaned), and receipt of four-month vaccines (complete or incomplete), in accordance with past analyses of potential confounders for these data.[146] We also adjusted for age in days at time of stool collection, to account for samples collected outside the 6-month window (N=62 kids with stool samples collected more than +/- 21 days outside the target window; min age in days at collection = 163 max = 256). For growth, in addition to the aforementioned covariates we also adjusted for maternal height and birth anthropometry (length-for-gestational-age z-score [LGAZ]), and breastfeeding in the first six months of life (exclusive/predominant vs none/weaned) based on daily breastfeeding data. As with enteric infection, we adjusted for age in days at the time of the two-year study visit (N=18 kids with 2-year anthropometry collected more than +/- 21 days outside the target window; min age in days at collection = 717 max = 823). We also excluded children whose mothers identified as Indigenous (N=2) from the growth dataset given substantial differences reported in that population in prior work in our study area.[174]

We included remoteness (location on the urban-rural gradient) as a fixed effect in all models to account for potential community clustering.

Data Analysis

Analysis steps are described alongside the research questions (RQs) they addressed.

RQ1: Are enteric infections and stunting distributed unequally by wealth in our population?

We used the Concentration Index and concentration curves[175–177] to assess if the burden of our health outcomes of interest was distributed inequitably by wealth in our study populations.

We plotted the cumulative percent of the health outcome of interest against the cumulative percent of ranked inequality using our ranked wealth variable. We used the linear regression Delta calculation method including robust standard errors and applied the Erreygers correction[178] using the rineq package[179] in R version 4.4.2 to calculate the Concentration Index as the area between the curve and the line, where a negative value corresponds to higher concentration of the outcome among the poor.

RQ2: Does household WASH or household wealth protect against any enteric infection or HiC?

RQ3: Does household WASH or household wealth protect against stunting?

We used multivariate logistic regression (binary outcomes no infection, HiC, and stunting) and linear regression (continuous outcome LAZ) models to test for relationships between the outcomes of interest [RQ2 and RQ3] and the exposures of complete household WASH and household wealth. We adjusted for the covariates described above.

Does prevalence of any infection, HiC, or stunting vary by household WASH status and household wealth?

We had defined this research question *a priori* but determined that we were very likely underpowered to detect effect modification in our statistical models given our small sample size. We conducted a sensitivity analysis adding an interaction term between household wealth and household WASH to the models described above, and found no evidence of interaction based on statistical significance, as we predicted. Given these sample size constraints, we conducted a stratified analysis to descriptively compare the prevalence of the health outcomes of interest, comparing households that had complete household WASH and were in the highest tertile of wealth to households that had incomplete household WASH and were in the lowest tertile of wealth.

RQ4: Does prevalence of any infection or HiC vary by household WASH status and season?

As described above, we were likely underpowered to detect effect modification by season in our models, although we had determined this question *a priori*, so we conducted sensitivity analyses adding an interaction term between season and WASH to the enteric infection models described above, again finding no statistically significant interaction. We therefore conducted a stratified analysis to descriptively explore differences in no infection and HiC, comparing prevalence in different seasons and under different household WASH coverage contexts.

Ethics approvals

The ECoMiD study was originally approved by institutional review boards at Emory University (IRB00101202) and the Universidad San Francisco de Quito (2018–022M), and currently has approval at the University of Washington (STUDY00014270) and USFQ. It was also approved by the Ecuadorian Ministry of Health (MSPCURI000253-4).

RESULTS

Prevalence of enteric infection and co-infection at six months of age in our study was high: of the 324 children with infection data available at six months, 90% had at least one infection, 75% had at least one co-infection, 32% had four or more co-infections, and 5% had six or more (Table 1). Of the 295 children with growth data available at 24 months, 12% were stunted (median length-for-age Z-score -0.760 [-3.98 - 3.80]), 2% were wasted, and 4% were underweight at 24 months of age.

RQ1: Are enteric infections and stunting distributed unequally by wealth in our population?

We assessed the equality in the distribution of no infection, HiC, and stunting using concentration curves and the concentration index (CI). While neither concentration index estimate was statistically significant at the 0.05 level, the position of the curves above the line of perfect equality suggests a marginally higher concentration of both stunting (0.05 [-0.13-0.03]) and HiC (-0.06 [-0.18-0.06]) among the poorest households in our study, but no inequality for absence of infection, for which the curve crossed the line on several occasions (0.01 [-0.07-0.08]) (Figure 1).

RQ2: Does household WASH or household wealth protect against any enteric infection or HiC?

Having complete household WASH (at least basic or limited water, sanitation, and hygiene coverage) was protective against HiC (aOR 0.56 95%CI 0.32-0.97) (Table 2 model 1b), and this effect was even greater in a secondary analysis looking at six or more enteric coinfections (aOR 0.27 95%CI 0.08-0.93) (Supplemental Table 1). The opposite trend was observed for odds of being uninfected with any enteric pathogen (aOR 1.42 [95%CI 0.56-3.55], Table 2 model 1a), although this result was not statistically significant.

We did not find evidence of a protective effect of household wealth against HiC (aOR 0.91 [95%CI 0.70-1.23]), nor did we find evidence that household wealth predicted having no enteric infections (aOR 0.89 [0.57-1.38]) (Table 2 model 1 a & b).

Prevalence of HiC in households in the wealthiest tertile with complete WASH (25%) was lower than in in poorer households with incomplete WASH (40%), and prevalence was highest among wealthy households with incomplete WASH (44%) (Figure 2, Supplemental Table 2). Similarly, prevalence of no infection was highest (10%) among wealthier households with complete WASH, compared to 6% of poorer households with incomplete WASH, and lowest among wealth households with incomplete WASH (0%). Complete WASH appeared to be more important than wealth in determining probability of HiC (Figure 2), and WASH and wealth were only weakly correlated in the data set (0.23 Spearman's rank correlation coefficient).

RQ3: Does household WASH or household wealth protect against stunting?

Having complete household WASH showed a weak potential association with LAZ score in the linear model, though this result was not statistically significant (mean increase of 0.25 [95%CI -0.10-0.60]) (Table 2 model 2a). We did not find evidence of an association between WASH and odds of stunting in the logistic regression model (aOR 0.85 [95%CI 0.29-2.55]).

Household wealth was predictive of a small but statistically significant difference in LAZ score in the linear model (mean difference of 0.20 LAZ comparing two houses differing by one SD in wealth, 95%CI 0.03-0.38, Table 2 model 2b). We did not find evidence that wealth was associated with stunting (aOR 0.83 95%CI 0.46-1.52) (Table 2, model 2a).

Among households in the wealthiest tertile with complete WASH, prevalence of stunting was just 4%, compared to 11% of children in the poorest tertile with incomplete WASH; prevalence was highest among poor households with complete WASH (22%) (Figure 2,

Supplemental Table 2). Wealth appeared to be important in determining prevalence of stunting among households with complete WASH, but not among households with incomplete WASH (Figure 2). Households with complete WASH had lower prevalence of stunting than households with incomplete WASH among the wealthy, but this relationship was reversed among poorer households.

RQ4: Does prevalence of any infection or HiC vary by household WASH status and season?

In our stratified analysis examining the prevalence of no infection and HiC under different household WASH and seasonal contexts, we found that the difference in prevalence of HiC based on household WASH status was greatest in the dry season (dry season: 24.7% in households with complete WASH vs 45.3% in households with incomplete WASH, rainy season: 27.3% vs 36.0%) (Figure 3, Supplemental Table 3).

Notably, prevalence of no infection reflected a similar pattern, where prevalence of no infection was higher in households with complete WASH compared to incomplete WASH in the dry season, but the difference in prevalence by WASH status was minimal in the rainy season (Figure 3, Supplemental Table 3).

DISCUSSION

Summary of findings

We found that complete household WASH coverage was protective against HiC, but we did not find evidence it was protective against poor child growth outcomes. We did not find evidence that wealth was protective against enteric infections, and although it was associated with a small increase in LAZ, this increase did not appear to translate into protection against stunting. Seasonal variation in prevalence of enteric infection was dampened in households that had complete household WASH. Despite the lack of evidence that household wealth offered direct health benefits related to our outcomes of interest, the inequitable distribution of stunting and HiC among the poorest study households indicates that socioeconomic inequities still need to be addressed.

Protective potential of household WASH

Having complete WASH was associated with a 44% reduction in the odds of HiC, and a 73% reduction in odds of infection with six or more enteric pathogens. These WASH-related reductions in infection are an important finding given the mixed results on diarrhea and child growth from recent studies,[36–39] and are consistent with recent findings from our study group.[146] Although we did not consider diarrhea as an outcome of interest in this study, enteric infections can have health consequences even absent clinical manifestation,[180] and their prevention has multiple health benefits.

Despite the protective effect of household WASH at high levels of co-infection, 90% of children in our study population had at least one enteric infection, indicating that transmission of enteric pathogens is highly prevalent across all strata. Past research in Ecuador found that elements of household WASH, particularly related to water, may be less protective in high-transmission regions.[181] It is possible that more transformative WASH than what is available in our study communities is needed for children to remain free of enteric infections entirely,

although our research group recently found a protective effect of improved sanitation against any infection.[146]

A variety of infrastructure conditions exist in the study area, but no one ECoMiD community has universal coverage with both perceived high-quality, consistent piped water and with sewer connections or septic tanks where waste is routinely properly disposed of. Our measurement of complete household WASH was based on our ability to disaggregate our data according to JMP definitions,[144] and we were unable to precisely estimate safely managed access, which would better reflect a potentially transformative WASH setting. It is likely that few of our study households would qualify as having safely managed WASH, given the constraints described above. The scale up of safely managed services might be better able to reduce levels of infection with any pathogen.

We did not find evidence that household WASH had an effect on either length-for-age Z-score or stunting in this study. A meta-analysis of 33 cohorts on child growth found that pre-conception, pre-natal, and early post-natal periods were the most important time periods to intervene on to improve child growth.[182,183] Future nutritional interventions at those time points, delivered alone or as a part of transformative WASH, are thus more likely to improve child growth than WASH interventions alone.[184]

Protective potential of household wealth

We did not find evidence that wealth was protective against enteric infections. These results suggest that household wealth alone may be limited in its ability to provide households with the means to overcome poor community or environmental conditions, which is consistent with frameworks that consider households and individuals to be limited by higher level constraints, and with research that has found limited effects of household WASH in highly contaminated settings.[41] Poverty and rural livelihoods are particular risk factors for the spread of infections which have environmental reservoirs, including many enteric infections.[185]

Wealth did have a small beneficial effect on linear child growth, but this did not appear to translate to a protective effect against stunting. The benefit of wealth on LAZ was consistent with findings from a recent meta-analysis on child growth.[182,183] This protective effect of wealth could be a result of pathways from wealth to health via improved nutrition or dietary diversity, which may also be improved via access to financial resources.

Given that LAZ and stunting are related, there is some plausibility that wealth might ultimately improve stunting rates if achievements in improved LAZ were great enough. Similarly to the limitations identified for household WASH interventions operating in isolation, it is possible that much larger improvements in wealth and standard of living than what our study captured may be needed to reduce stunting rates.[123]

A study in Ecuador found that stunting in children under-five burdened households in the poorest wealth tertile most substantially at the national level,[186] reflecting our findings on the inequitable distribution of stunting among our study households.

Interplay between WASH and wealth

Globally, there are important disparities in WASH access by socioeconomic status between and within countries.[17] Wealth is associated with WASH access,[17] and even in the absence of direct health benefits, improved access has numerous indirect benefits for human wellbeing.[187] Given these relationships, it is possible that in our study, wealth is operating primarily through pathways that include covariates we adjusted for in our models, such as wealth – WASH – health,[119] or wealth – type of community – health, which would bias our effect estimate of wealth on health towards the null. However, we detected only weak correlation (~0.23) between the household WASH and household wealth variables in our data set.

In our stratified analysis, our health outcomes of interest were consistently better among households in the wealthiest tertile with complete WASH, compared to households in the poorest tertile with incomplete WASH. Household WASH status seemed to be more important to

enteric infection prevalence than wealth, consistent with the findings from our models. However, stratification of stunting prevalence showed a more interesting pattern. Prevalence of stunting was only lower among households with complete compared to incomplete WASH among households in the wealthiest tertile, and prevalence was only lower among wealthier households vs poorer among households with complete WASH. These results indicate some level of interplay between the two conditions, and research has identified an overlapping burden of lack of access to WASH and stunting in many countries, and particularly among the poorest segment of the population.[149]

Interplay between season and WASH

We found that coverage with complete household WASH damped seasonal variation in HiC: prevalence of HiC was similar in the dry and rainy seasons in households with complete WASH, but higher in the dry vs rainy seasons in households without complete WASH. Previous research from our group found that infection with any virus was higher during the dry season, and infection with any bacteria higher during the rainy season,[146] which is consistent with specific pathogen etiologies.[167,168] It is possible that these results reflect better household WASH effectiveness against specific viral pathogens driving seasonal transmission, and further research could better quantify this relationship.

The difference in prevalence of both no infection and HiC, comparing households with complete and incomplete WASH, was greatest in the dry season, which may indicate that having WASH coverage is more important to health during those months. This finding is consistent with a systematic review and metanalysis that found increased benefits from household WASH interventions on diarrhea prevention during the dry season.[87] However, recent studies in Bangladesh found that WASH interventions to reduce diarrhea were most effective during the monsoon (rainy) season,[86,170] indicating that local geographic and climate conditions may effect WASH intervention viability differently.

In the region of Esmeraldas, the dry season tends to put greater pressure on individuals to cope with more limited access to water, as rivers recede and rains are less frequent.[63,92,134] Households turn to less preferred water sources, such as expensive bottled water purchasing, or have to walk greater distances and extend more labor to access water during the dry season.[63,92,134] As such, household WASH connections to pipes likely make a greater difference both for access to drinking water and to water for personal hygiene in the dry season. Coping behaviors have been found to increase in the face of water scarcity,[82,83] and the financial costs of water coping are high,[84] so it seems reasonable to expect that access wealth would also be most important to ECoMiD households during the dry season, potentially mitigated by access to household WASH.

Strengths and limitations

This study has several limitations to consider. First, we were unable to statistically test for effect modification due to our small sample size. A recent study that included close to 5,000 children and 8,500 diarrheal measurements in rural Bangladesh was able to successfully test for effect modification between WASH and wealth and WASH and season, and found evidence of an interaction between WASH and season at the <0.05 level and between WASH and wealth at the <0.1 level.[86] Even that study was underpowered to detect joint effect modification between the three factors. Given the modelling limitations, stratification represents a useful secondary approach to considering variation. In general, we were likely underpowered to detect associations, and cannot rule out the possibility that there was an association we were unable to detect given our limited sample size.

The inclusion of additional outcome variables related to satisfaction and quality of life would have helped us to better assess the indirect benefits of WASH access. ECoMiD did not collect data on satisfaction or other quality of life related measurements (e.g., SanQoL).[47] Future surveys in the study area could include these metrics to better assess community perspectives.

Our analysis benefited from a rich dataset that includes a wide array of information on household conditions, numerous environmental and biological samples, anthropometry, and behaviors. We were able to capture a broad array of covariates in our models to increase the precision of our estimates. In addition, the study location includes a range of remoteness settings spanning urban to intermediate to rural, and as such our findings are broadly generalizable to a range of living conditions and contexts.

Conclusion

Given the protective effect of WASH on HiC alongside the persistence of high levels of enteric infection more generally, efforts to protect children from enteric diseases likely need to scale up transformative WASH interventions that reduce environmental contamination, particularly during the dry season. Given that neither WASH nor wealth appeared to reduce stunting in our study, proven nutritional interventions targeting maternal health before and during pregnancy and early infant exposures should be incorporated into transformative WASH programs. The poorest households are the most impacted by enteric infection and stunting, and interventions must take an equity approach to ensure child health for all.

TABLES AND FIGURES

Table 1: Health outcomes among children in the ECoMiD cohort. Prevalence based on data available for a) enteric infection at 6 months (N=324) and b) growth at 24 months (N=295)

Infections (non-COVID)		Growth outcomes	
Total # infections	Median = 3 (Min=0, Max=8)	**Length-for-age Z-score**	-0.760 [-3.98, 3.80]
0	33 (10.2%)		
1	49 (15.1%)	**Stunted**	36 (12.2%)
2	68 (21.0%)	**Wasted**	7 (2.4%)
3	70 (21.6%)	**Underweight**	12 (4.1%)
4	45 (13.9%)		
5	42 (13.0%)		
6	13 (4.0%)		
7	3 (0.9%)		
8	1 (0.3%)		
2+ co-infections	242 (74.7%)		
4+ co-infections	104 (32.1%)		
6+ co-infections	17 (5.2%)		

Stunted defined as length-for-age Z-score <-2; Wasted defined as weight-for-length Z-score <-2, Underweight defined as weight-for-age Z-score <-2 WHO 2006 Growth Standards

Table 2: Multivariable model results for the outcomes of no infection, high enteric co-infection (HiC), length-for-age Z-score (LAZ), and stunting. Results from logistic regression models 1a, 1b, and 2b are shown as adjusted odds ratios alongside their corresponding 95% confidence intervals (CIs); results from the linear regression model 2a shown as difference in mean LAZ alongside 95% CIs. *P*-values <0.05 shown in bold.

	Adjusted odds ratio (OR) or mean difference and 95% CI	***P*-value**
Model 1a outcome: No infection (OR)		
Complete HH WASH (vs incomplete)	1.42 (0.56-3.55)	0.46
Scaled HH wealth score	0.89 (0.57-1.38)	0.59
Rainy season (vs dry)	0.50 (0.21-1.18)	0.12
Model 1b outcome: High enteric co-infection (OR)		
Complete HH WASH (vs incomplete)	0.56 (0.32-0.97)	**0.04**
Scaled HH wealth score	0.91 (0.68-1.21)	0.51
Rainy season (vs dry)	0.86 (0.51-1.45)	0.56
Model 2a outcome: Length-for-age Z-score (mean change)		
Complete HH WASH (vs incomplete)	0.25 (-0.10-0.60)	0.16
Scaled HH wealth score	0.20 (0.03-0.38)	**0.02**
Model 2b outcome: Stunting (OR)		
Complete HH WASH (vs incomplete)	0.85 (0.29-2.55)	0.78
Scaled HH wealth score	0.83 (0.46-1.52)	0.55
Models 1a and 1b adjusted for remoteness, vaccine completion, child sex, maternal education, maternal ethnicity, exclusive breastfeeding in the last 14 days, child age in days at sample collection. Models 2a and 2b adjusted for remoteness, child sex, maternal height, maternal ethnicity, maternal education, maternal age, exclusive breastfeeding in the first 6 months of life, child age in days at measurement, birth anthropometry		

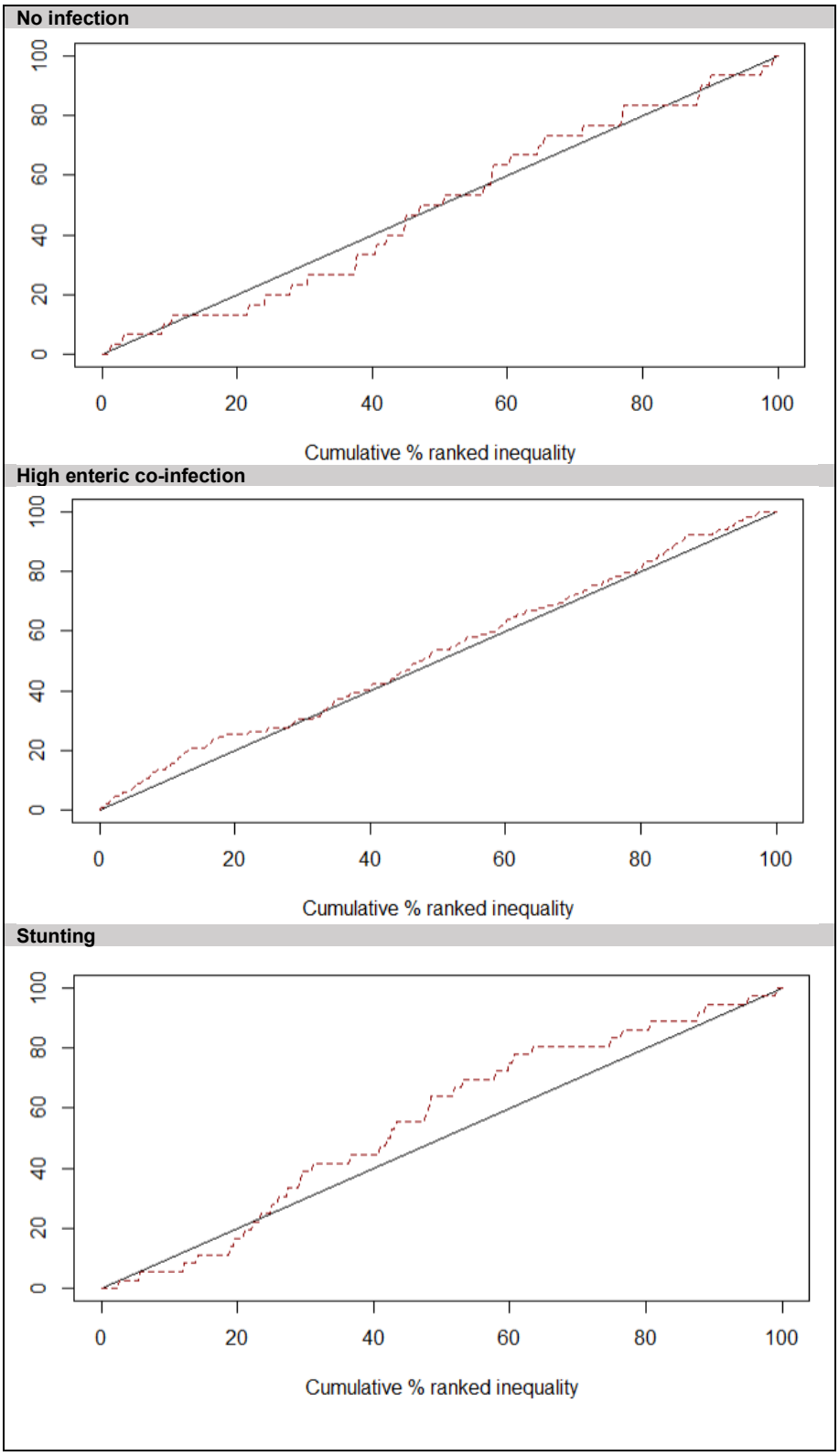


Figure 1: Concentration curves for no infection, high enteric co-infection (HiC), and stunting. The Y-axis shows cumulative % of the outcome, the X-axis shows cumulative % ranked inequality. When the curve (red) is above the line of equality (black), this indicates concentration of the health outcome among poorer households.

Figure 2: Infection and stunting prevalence stratified by household water, sanitation, and hygiene and wealth. Proportion of children a) with no infection, b) high enteric co-infection (HiC), and c) stunting shown stratified by percentile of household wealth on the x-axis and colored by household WASH coverage (complete household WASH defined as at least basic or limited water, sanitation, and basic hygiene in a household).

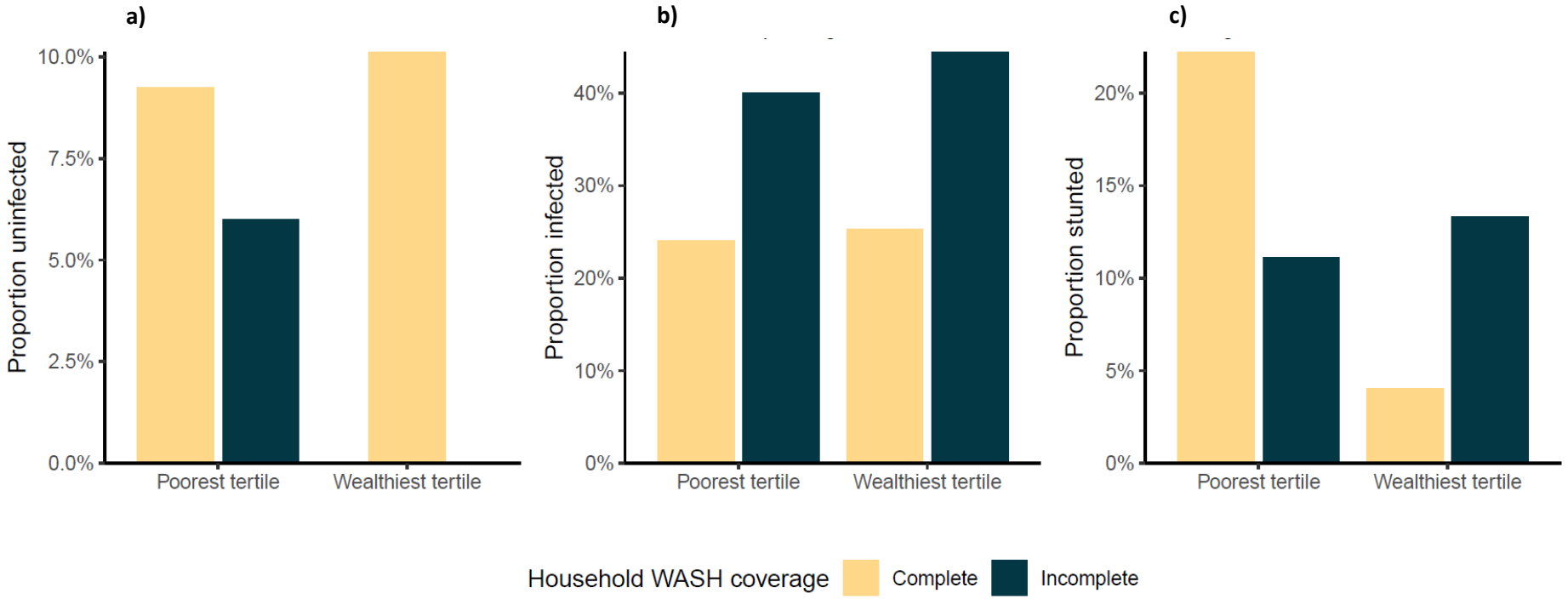
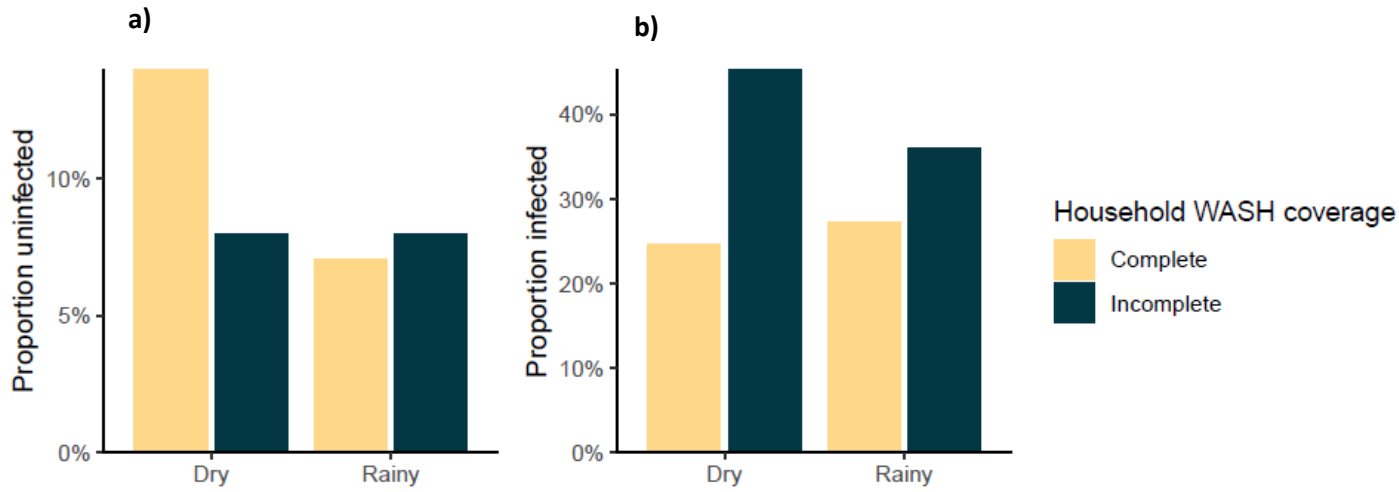


Figure 3: Infection prevalence stratified by household water, sanitation, and hygiene and season. Proportion of children a) with no infection and b) high enteric co-infection (HiC) shown stratified by season on the x-axis and colored by household WASH coverage (complete household WASH defined as at least basic or limited water, sanitation, and basic hygiene in a household).



SUPPLEMENTAL TABLES AND FIGURES

Table 2: Multivariable model results for the outcome six or more enteric co-infections. Results from the logistic regression model are shown as adjusted odds ratios alongside their corresponding 95% confidence intervals (CIs). *P*-values <0.05 shown in bold.

	aOR and 95% CI	*P*-value
Six+ enteric coinfections		
Complete HH WASH (vs. incomplete)	0.27 (0.08-0.93)	**0.04**
Scaled HH wealth score	0.86 (0.42-1.74)	0.67
Rainy season (vs. dry)	0.84 (0.27-2.57)	0.76
Adjusted for remoteness, vaccine completion, child sex, maternal education, maternal ethnicity, exclusive breastfeeding in the last 14 days, child age in days at sample collection.		

Supplemental table 2: Stratified analysis of the prevalence of no infection, high enteric co-infection (HiC), and stunting by household water, sanitation, and hygiene (WASH), and wealth status. Complete household WASH defined as at least basic or limited water, sanitation, and basic hygiene in a household. Household wealth presented comparing the wealthiest to the poorest tertile.

	Incomplete HH WASH		Complete HH WASH	
	Poorest Tertile (N=50)	Wealthiest Tertile (N=27)	Poorest Tertile (N=54)	Wealthiest Tertile (N=79)
No infection	3 (6.0%)	0 (0%)	5 (9.3%)	8 (10.1%)
High enteric co-infection	20 (40.0%)	12 (44.4%)	13 (24.1%)	20 (25.3%)
Six+ enteric co-infections	3 (6.0%)	2 (7.4%)	2 (3.7%)	1 (1.3%)
Stunting	5 (11.1%)	4 (13.3%)	10 (22.2%)	3 (4.1%)

Supplemental Table 3: Stratified analysis of the prevalence of no infection and high enteric co-infection (HiC) by household water, sanitation, and hygiene (WASH) and season. Complete household WASH defined as at least basic or limited water, sanitation, and basic hygiene in a household. Season defined as season in which the stool sample was collected.

	Dry		Rainy	
	Incomplete HH WASH (N=75)	Complete HH WASH (N=93)	Incomplete HH WASH (N=50)	Complete HH WASH (N=99)
No infection	8.0% (6)	14.0% (13)	8.0% (4)	7.1% (7)
High enteric co-infection	45.3% (34)	24.7% (23)	36.0% (18)	27.3% (27)
Six+ enteric co-infections	9.3% (7)	2.2% (2)	10.0% (5)	3.0% (3)

Chapter 5: Conclusions

This dissertation uses mixed-methods and a socioecological framework to demonstrate the complex interplay between the scales at which WASH access occurs, and to understand the challenges to and health consequences of lack of access. Throughout, we use the lived experience of women and mothers to contextualize the epidemiological data we analyze and interpret. In Chapter 2, we show that individuals, and in particular mothers, are limited in their ability to make WASH and health-related decisions by every layer above them in the socioecological framework, and that the financial and labor burden of obtaining WASH is highest for the poorest households with the least community infrastructure. In Chapter 3, we confirm that wealth increases WASH access at the household level, and identify high thresholds of wealth to obtain WASH access and priority WASH hardware, as defined by community members. In Chapter 4, we further highlight the important but often limited effects of household WASH interventions in isolation by showing that, while household WASH protected study children against high levels of enteric co-infection and mitigated seasonal variation in infection, prevalence of any infection remained high, and we did not find evidence that WASH protected against poor child growth.

Together, our results emphasize that focusing on individuals in WASH research is both highly necessary, from an informative perspective, and completely insufficient, from an intervention perspective. The use of qualitative methods allowed us to better understand maternal choice in WASH and various drivers of choice that are primarily outside the control of the individual (e.g., cost, household ownership, infrastructure quality and connection, season and remoteness). Maternal choice is also relevant to decision making around nutrition and child feeding that can improve child growth. For both processes, wealth could be considered an enabler of choice and the means of counteracting some broader constraints. In practice, this means that women would need to have equal control over financial related decision-making in

the household. Women's empowerment is considered essential to achieving numerous health goals,[188] including WASH related access and child nutrition.[189,190]

This work also highlights the importance of considering climate and seasonal conditions in WASH interventions. Extreme weather events are increasing under climate change, and both droughts and floods have substantial implications for WASH resources. Seasonal changes increase both the cost and labor of collecting water. Not only do household-level WASH interventions need to take climate into consideration, but climate change resiliency, adaptation, and support must be built-in at broader community (e.g., infrastructural) and national policy levels to prevent the poorest households from bearing the brunt of the effects of climate change.

Future research

"Health inequity is the central embodiment of our civilization."

-Jaime Breilh, Critical Epidemiology and the People's Health[191]

It seems fitting to close with some perspectives from Jaime Breilh, an Ecuadorian scholar and one of the developers of critical Latin American epidemiology. He highlights the importance of contextualizing epidemiolocal findings within their sociopolitical and historical structures. He wrote,

"Conventional applications of statistics do not study real variation, but, rather, a constructed trimmed-down variation… that discards all types of phenomena in the social context that do not comply with strict probabilistic validity, considering them as statistical 'noise.'… Empirical geography of health limits itself to describing the spatial distribution of risk factors or health indicators, stripping place and factors of their historicity, movement, and contradictions… drained of their significance as health-determining processes."[191]

In this dissertation, we chose to contextualize our epidemiological findings primarily with the lived experiences of our study mothers, rather than with broader sociopolitical historical

context. Future work in this area could expand on the sociopolitical framework to conduct community-level analyses that take an explicitly sociopolitical approach to data analysis. The socioecological framework illustrates how the broader systems generating existing inequities must be addressed, and supports the argument to broaden the measurement of the benefits of WASH access dramatically, in line with the far reaching effects that WASH access has on life, from school attendance, to safety, to debts and daily stress.[192,193]

Recommendations

Our results underscore the importance of including and responding to community perspectives and needs in WASH,[28,194] and ultimately in all health-related research that aims to improve living conditions globally. Our work suggests that both wealth and WASH access should be increased, particularly among the poorest, to improve equity as well as individual (particularly women's) agency to practice healthy behaviors and make health-related decisions.

From an intervention perspective, perhaps transformative WASH could be re-conceptualized as transformative community well-being, consistent with Sumak Kawsay, while also addressing the specific needs expressed by community members (e.g., for clean water and piped household connections). The difficulty in improving the stubborn health burdens of enteric infection and stunting suggests a need for multifaceted approaches that target multiple conditions simultaneously to have a substantial impact on child health.[149] Transformative WASH as currently understood would incorporate universal high quality WASH access with other interventions to reduce fecal contamination in the environment,[195] and some have suggested the co-delivery of important nutritional interventions. The incorporation of poverty alleviation and expanded home ownership more broadly, particularly through the dismantling of racist, settler colonial systems and systems of economic exploitation, could have a dramatic impact on livelihoods that could improve community health, equity, and well-being. This conceptualization

of transformative community well-being would also recognize and value the non-health benefits of WASH access and of transformed communities more broadly.

In the short term, WASH practitioners might consider addressing the community need for clean drinking water in addition to the need for access to piped water in the home to save costs and labor on chores. Interventions targeting the later need could use different approaches, including water recycling. Further, there is a clear desire for WASH technology such as cisterns, wells, and water tanks, and provision of such resources would further address community needs. Efforts to improve quality and consistency of access to piped water, including small-scale electrical projects that could maintain access during power outages, could improve public trust in piped networks and reduce reliance on costly and unsustainable bottled water purchasing. Businesses and non-profits could continue to explore temporary or mobile/transferrable water storage and sanitation solutions for unstable or unowned housing contexts. Whatever the intervention, climate resiliency should be built into the design in preparation for seasonal droughts and floods, and community feedback should continue to be elicited throughout development and implementation.

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