Distribution Agreement

In presenting this thesis or dissertation as a partial fulfillment of the requirements for an advanced degree from Emory University, I hereby grant to Emory University and its agents the non-exclusive license to archive, make accessible, and display my thesis or dissertation in whole or in part in all forms of media, now or hereafter known, including display on the world wide web. I understand that I may select some access restrictions as part of the online submission of this thesis or dissertation. I retain all ownership rights to the copyright of the thesis or dissertation. I also retain the right to use in future works (such as articles or books) all or part of this thesis or dissertation.

Signature:

_____.	4/18/2022
Nicholas R. Laramee	Date

Exposure to animals, animal feces, and animal feces-contaminated environments for children under two years in households that own animals in Northwestern Ecuador: a qualitative research study

By

Nicholas R. Laramee
Master of Public Health

Hubert Department of Global Health

_____

Bethany Caruso, PhD, MPH
Committee Chair

_____

April Ballard, MPH
Committee Member

Exposure to animals, animal feces, and animal feces-contaminated environments for children under two years in households that own animals in Northwestern Ecuador: a qualitative research study

By

Nicholas R. Laramee

Bachelor of Science
University of South Carolina
2015

Thesis Committee Chair: Bethany Caruso, PhD, MPH

An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfilment of the requirements for the degree of
Master of Public Health in
Global Health
2022

Abstract

Exposure to animals, animal feces, and animal feces-contaminated environments for children under two years in households that own animals in Northwestern Ecuador: a qualitative research study

By Nicholas R. Laramee

Low- and middle-income countries (LMICs) in South America, such as Ecuador, are estimated to have a high burden of child mortality from adverse health outcomes. Studies suggest that these negative health outcomes are occurring from child exposure to animal and animal feces. Existing research does not adequately explain if, how, to what extent, and what conditions children are exposed to animals and animal feces in households that own domesticated animals in Northwestern Ecuador.

Go-along in-depth interviews (IDIs) and a survey were utilized to explore exposure to animals, animal feces, and fecal contaminated environments among children under 2 years of age, as well as interpersonal dynamics and influences of exposure in households that own animals. From February to April 2021, 32 IDIs and surveys were conducted in Spanish with mothers ages 19-47 years old along an urban-rural gradient. IDIs were completed with mothers of children ages 10-18 months old to gain insight on the following topics of interest: exposure inside the household, exposure outside but near the household, and exposure at non-household locations.

Participants discussed exposure to animals and animal feces occurring inside the house, outside as well as near the household and even at non-household locations. These non-household locations included relatives, businesses, and neighbor's houses. The exposure to owned and stray domestic animals varied depending on locations, with most exposure occurring with domestic animals and feces being from cats, dogs, and creole chickens. Many participants revealed that interpersonal dynamics with family members, household characteristics, and their own behaviors influenced child exposure to animals, animal feces, and fecal contaminated environments. The participants also reported child exposure occurring across the urban-rural gradient in Northwestern Ecuador, which seemed to vary.

The findings of this study help explain child exposure to animals and animal feces occurring inside households, outside but near households, and at non-household locations. The findings of this study can be used to inform a quantitative survey to better characterize child exposure risk to animals and their feces in Northwestern Ecuador as well as inform future interventions how to effectively decrease exposure to pathogens from animals in Ecuador.

(Word Count: 346)

Exposure to animals, animal feces, and animal feces-contaminated environments for children under two years in households that own animals in Northwestern Ecuador: a qualitative research study

By

Nicholas R. Laramee

Bachelor of Science
University of South Carolina
2015

Thesis Committee Chair: Bethany Caruso, PhD, MPH

A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfilment of the requirements for the degree of
Master of Public Health
in Global Health
2022

Acknowledgements

Thank you to my thesis chair, Bethany Caruso, for her invaluable support and encouragement in conducting this study and assistance with developing the thesis manuscript. I would also like to thank my thesis committee member, April Ballard, for her implementation of this research project and allowing me to come on board to assist in analyzing the qualitative data for one cohort of the study. Additionally, I would like to thank Karen Levy and her research team Lee et al for conducting the Ecomid cohort study and for granting me permission to use data from their study. Lastly, I would like to thank the Ecuadorian people in the communities where this study was conducted for their participation and invaluable insight. Without all of these people, this thesis would have not been possible.

Table of Contents

Acronym List

WASH: Water, Sanitation and Hygiene
EED: Environmental enteric dysfunction
LMIC: Low- and middle-income countries
WHO: World Health Organization
FAO: Food and Agriculture Organization
HAZ: Height-for-age Z-scores
HIC: High-income countries
IDIs: In-Depth Interviews
UN: United Nations
RCT: Randomized-control trial
MADCH: Maternal and Animal-related Determinants of Child Health framework
UNICEF: United Nations Children's Fund
LNS: Lipid-Based Nutrient Supplement

Chapter 1: Introduction

Low- and middle-income countries (LMICs) have a high proportion of children with negative health outcomes, such as diarrhea, environmental enteric dysfunction (EED), stunting and cognitive issues (Penakalapati et al., 2017). These negative health outcomes are leading to high rates of deaths in LMICs, especially from diarrhea in children under 5 years of age according to the Global Burden of Disease 2015 report (Wang et al., 2016). To combat the adverse health outcomes and high mortality in children of LMICs, global water, sanitation, and hygiene (WASH) interventions have been implemented for years to increase access to safe drinking water and sanitation services and handwashing facilities (World Health Organization & United Nations Children's Fund, 2021).

A systematic review and meta-analysis indicated that sanitation decreased diarrhea by 30-40% in children in LMICs (Freeman et al., 2017). However, several recent studies have shown that WASH interventions in LMICs have not found consistent evidence that these interventions are leading to a decrease of diarrhea incidence, decrease of fecal contamination in water storage, improvement on growth outcomes and malnutrition, or a decrease in soil-transmitted infections (Delahoy et al., 2018). These studies show that WASH interventions do not disrupt all the pathways of infectious diseases and feces for children (Delahoy et al., 2018). This may be from many sanitation interventions focusing heavily on the fecal-oral transmission pathway from human feces, following the traditional F-Diagram that Delahoy et al (2018) outlined (Delahoy et al., 2018).

Although this human fecal-oral transmission pathway is essential in sanitation interventions, it's important to recognize that there is another chain of transmission occurring between animal feces and humans.

The Food and Agricultural Organization (FAO) reported in 2017 that domestic animals generate roughly 85% of the world's animal feces (Food and Agriculture Organization of the United Nations (FAO), n.d.). The risk of exposure to animals and animal feces for adults and their children are even greater in LMICs than high-income countries (HICs), because domestic animal ownership and animal production is more common in rural and urban households in LMICs (Delahoy et al., 2018; Penakalapati et al., 2017). Disposal of animal feces at the household level does not occur frequently, allowing fecal-oral transmission of zoonotic pathogen through direct contact with animals, animal feces, and/or fecal contaminated water, food and fomites (Delahoy et al., 2018). Additionally, some studies have linked child exposure to animals, animal feces ,and feces-contaminated environments to adverse health outcomes in children in LMICs, such a diarrhea, EED, and malnutrition,(Delahoy et al., 2018). Although there is some knowledge of child exposure to animals and animal feces in LMICs, there are still gaps that persist.

In LMICs in South America, such as Ecuador, this gap of research on child exposure to animals, animal feces, and fecal contaminated environments is evident. Most research of child exposure to animals and animal feces are from studies in Africa and South Asia (Clasen et al., 2014; Ercumen et al., 2017; Luby et al., 2018; Null et al., 2018; Rosenbaum et al., 2021). A few studies conducted in LMICs of South America have shown that the high number of children with negative health outcomes is possibly due to exposure to animals, animal feces and fecal contaminated environments(Grados et al., 1988a; Lowenstein et al., 2020; Marquis et al., 1990; Vasco et al., 2016). Specifically, in Ecuador there are few studies on the animal and animal feces transmission pathway and impact on child health. A study in a semi-rural area found that the main transmission route for several zoonotic pathogens in humans is from direct contact with

animals and/or the fecal contaminated environment (Vasco et al., 2016). Another study in Quito, Ecuador concluded that children may be at an increased risk for zoonotic infections if they regularly have contact with domestic animals (Lowenstein et al., 2020). Additional studies need to be conducted in urban and rural areas of Ecuador, and other LMICs of South America, to better understand and characterize child exposure to animals, animal feces and fecal-contaminated environments.

Problem Statement

There is a breadth of research in LMICs showing that many children are having adverse infectious disease outcomes, such as diarrhea, EED, and stunting. These negative health outcomes should be preventable in these countries, with many WASH interventions mitigating the amount of negative health outcomes in these children. Unfortunately, adverse infectious disease outcomes are still occurring in children in LMICs despite implementation of WASH interventions. One reason may be that these WASH interventions focus on mitigating the fecal-oral transmission pathway from human feces, placing little emphasis on human contact with animal feces in rural and urban communities (Penakalapati et al., 2017). The Food and Agriculture Organization estimated that domestic animals contribute to 85% of all animal fecal waster across to globe, mostly in LMICs (Food and Agriculture Organziation of the United Nations (FAO), n.d.). This shows that there is a large magnitude of animal feces in and around households in rural and urban communities, but there are gaps in understanding the exposure occurring between animal feces and children. Additionally, most of our current understanding of child exposure to domestic animals and animal feces is from research conducted in Africa and South Asia, with limited research in South America. Specifically in Ecuador, this gap of understanding of child exposure to animals and their feces exists. There are only two readily

available studies of zoonotic pathogens and transmission of these pathogens to children in Ecuador. There are no published studies in Ecuador, and few studies in other South American LMICs, that characterize child exposure to domestic animals, animal feces and the contaminated environment. There is a need to understand and characterize child exposure to animals, animal feces, and animal feces contaminated environments in Ecuador to help reduce adverse health outcomes, including child mortality.

Purpose Statement

This study intends to explore and characterize child exposure to animals, animal feces, and animal feces-contaminated environments using qualitative research methods to understand the fecal-oral transmission pathway between animal feces and children under two years of age along an urban-rural gradient in Northwestern Ecuador. This study will also provide detailed information on how, why, and to what extent children are exposed to animals, animal feces, and animal feces-contaminated environments, which could also guide future interventions at the households' level in Ecuador to reduce negative health outcomes, including child mortality.

Research Objective

There is a need to understand child exposure to animals, animal feces .and feces-contaminated environments in households in Ecuador in rural and urban areas in order to adequately describe the fecal-oral pathway from domestic animals and animal feces in children for effective WASH interventions in Northwestern Ecuador.

The aims of this study are as follows:

Aim 1: Describe if, how, to what extent, and under what conditions children under two years are exposed to animals, animal feces, and animal feces-contaminated environments in households that own animals in Northwestern Ecuador.

Aim 2: Examine how exposure varies along the urban-rural gradient in Northwestern Ecuador.

Significance Statement

The findings of this study can be utilized to design future interventions and programs and guide multidisciplinary research projects that target child health outcomes and exposure to animals and animal feces. Conclusions drawn from this study can guide future research and/or interventions that are specific to people in urban and rural communities in Northwestern Ecuador. Since the study is also exploratory in nature, the methodologies can be adapted for research studies in other regions of Ecuador or other LMICs regarding child exposure to animals, animal feces, and animal feces contaminated environments.

It is important to examine if exposure differ between households that own animals and households that do not own animals to determine households most at risk, if any. Findings from this study among household that own animals will be used to compare with a concurrent study on child exposure to animals, animal feces, and animal feces contaminated environments in households that do not own animals in Northwestern Ecuador. This qualitative data will also be used to inform a survey tool to quantitatively characterize child exposure risk to animals and animal feces.

Chapter 2: Literature Review

Introduction

Studies show that exposure to animals, animal feces, and animal feces-contaminated environments in LMICs can lead to diarrhea, EED, stunting, cognitive issues, and other health outcomes (Delahoy et al., 2018). WASH interventions focused on reducing exposure to animals, animal feces, and animal feces-contaminated environments have the potential to improve outcomes on child growth, diarrhea, environmental enteric dysfunction (EED), and cognitive development (Penakalapati et al., 2017). Unfortunately, most WASH interventions are not focused on this animal exposure pathway of fecal-oral transmission and its impacts on children in the first 2 years of life and there is limited research published (Penakalapati et al., 2017). This qualitative study explores infant exposure to animals and animal-source contamination in rural and urban areas in Northwestern Ecuador. This literature review discusses current research on the following topics: one health model and zoonotic disease transmission, limitations of current WASH interventions, exposure to animals/animal feces in LMICs, caregiver and child behavior/play practices with animals in households in LMICs, impacts of child exposure to animal feces in LMICs, and child exposure to animals and animal feces in Ecuador.

One Health Model and Zoonotic Disease Transmission

The exponential increase of new infectious disease outbreaks in the past ~30 years have led to an increasing recognition that emerging infectious diseases often originate at the intersection of human and animal ecosystems (Penakalapati et al., 2017). More specifically, almost 66% of human pathogens and 75% of emerging pathogens originate as zoonotic diseases (Jones et al., 2008). This recognition has led to the need for an inter-disciplinary approach to handling disease transmission ,and was a major factor in the creating of the One World One

Health movement in 2004 (Woldehanna & Zimicki, 2015). The One Health Model considers the intersection between people, animals, and the environment that might lead to and/or increase the threat of disease (Cunningham et al., 2017). The One Health Model focuses on large-scale changes and interactions such as anthropogenic land use changes, travel, transport, trade of animals and animal products, increased human-animal contact due to exponential human population increases, climate change, and more. These large-scale changes and interactions may lead to additional opportunities for transmission between animals and humans, often referred to as the "initial spillover event" (Woldehanna & Zimicki, 2015). Specifically, an "initial spillover event" is when an infectious disease performs antigenic shift from animals to humans, enabling an infectious disease once only transmissible in animals to become transmissible in humans. These large-scale changes and interactions will only continue to increase, making it more important for the One Health Model to be integrated into public health.

Since the creation of the One Health model in the early 2000s, the field has expanded considerably. This expanded One Health model emphasizes looking at all the factors that lead to zoonotic disease spillover and disease emergence at the local level, including social and ecological factors between animals, humans, and the environment. At the local level, this expanded model considers specific human activity such as "if, how, where, and when people interact with animals" (Woldehanna & Zimicki, 2015). It's helpful to look at both the animal and human sides of this interaction. From the animal side, it is believed that the prevalence of infected domestic and/or wild animals impacts the probability of transmission to humans. From the human side, it is believed that the probability of disease transmission to humans from animals is mainly affected by the probability of a human encountering infected animals or animal feces

(Woldehanna & Zimicki, 2015), which is often determined by the types of activities that people engage in with animals.

The expanded One Health model takes into consideration that human activity is influenced by multiple factors along the socio-economic model. This model specifically considers how complex social dynamics influence the type and frequency of contact by individuals, families, or communities with animals and the intensity of contact. Some of these complex social dynamics include household characteristics, social norms, settlement patterns, and livelihood systems (Woldehanna & Zimicki, 2015).

Household characteristics, such as socio-economic status and family structures, can play a role in if and how families are exposed to animal and animal excreta. Social norms can affect interactions with animals and exposure to zoonotic pathogens in a variety of ways, such as the kinds of animals that are considered suitable for pets or for children to play with (Woldehanna & Zimicki, 2015). Settlement patterns, such as the construction of houses, may affect the number and variety of animals that people may be exposed to (Woldehanna & Zimicki, 2015). Lastly, livelihood systems may impact if people have direct or indirect contact with animals (Woldehanna & Zimicki, 2015). Outside of these complex social dynamics, the model also considers biological characteristics of human individuals and public policy. Overall, this expanded One Health model provides further insights and details that should be considered when looking at zoonotic disease emergence globally.

The expanded One Health model was applied in a human-animal exposure study in rural and urban locations in Thailand and among two different ethnic groups in Lao PDR and used a mixed-method approach utilizing qualitative interviews and a quantitative survey to identify groups of people at risk of transmission of infectious diseases and factors that contribute to that

risk (Woldehanna & Zimicki, 2015). The researchers aimed to determine if the model was effective in documenting the extent of human exposure to animals and exploring the interaction of social and environmental factors that influence risk of transmission at the individual and community levels (Woldehanna & Zimicki, 2015). The qualitative interviews explored the "how", "when", "where" and "why" of exposure at the human-animal level, while the survey was used to quantify individual exposure to animals. This study identified some universal exposure to domestic animals in communities in the targeted areas and highlighted new insights on specific risks. Some of these risks included Hmong boys playing with poultry, Lao-Thai households with pigs coming indoors, and exposure to feces used as fertilizer (Woldehanna & Zimicki, 2015). Overall, this study showed that the expanded One Health model aids in gaining additional insights on risk factors for transmission of infectious diseases between animals and humans. This information about these risk factors can help public health professionals develop more targeted interventions to reduce risk. As our world becomes more urbanized and connected, incorporating the One Health model will be more and more important in public health at the domestic and international levels. Additionally, public health should start incorporating this expanded One Health model in future interventions to reduce exposure to animal pathogens, including in water, sanitation, and hygiene (WASH) interventions.

Limitations of Current WASH Interventions

Water, sanitation, and hygiene (WASH) interventions assisted countries across the globe to transition from having limited/basic WASH services to most of the population having access to safe WASH services. Specifically in 2020, it was estimated by JMP that "74% of the global population used safely managed drinking water services, 54% of the global population used safely managed sanitation services and 71% of the global population had basic handwashing

facilities with soap and water at home" (World Health Organization & United Nations Children's Fund, 2021). In addition to improved access to safe WASH services globally, effective WASH interventions have led to huge improvements in health outcomes in many countries, especially regarding child health and mortality (Cumming et al., 2019).

Despite the success of WASH as shown by many observational studies, there have been some randomized control trials (RCTs) conducted in low-income rural settings that have shown mixed effects of WASH interventions on diarrhea, soil-transmitted helminth (STH) infection, trachoma, and stunting (Humphrey et al., 2019; Luby et al., 2018; Null et al., 2018). The three RCTs of WASH interventions referred to above included the WASH-Benefits Bangladesh (WASH-B Bangladesh), the WASH-Benefits Kenya (WASH-B Kenya) and the Sanitation, Hygiene Infant Nutrition Efficacy Zimbabwe (SHINE) trials (Cumming et al., 2019). All three of these RCTs were conducted in a low-income, rural setting with a high burden of stunting. These studies also had similar WASH interventions implemented, except for the SHINE trial (Humphrey et al., 2019; Luby et al., 2018; Null et al., 2018). The two WASH-B trials included seven intervention groups: "water chlorination; sanitation; handwashing with soap; combined water chlorination, sanitation, and handwashing with soap (WASH), infant and young child feeding (IYCF), which consisted of counseling on complementary feeding and provision of small-quantity lipid-paste-nutrient supplement (LNS); IYCF combined with WASH; and control" (Humphrey et al., 2019; Luby et al., 2018; Null et al., 2018; Pickering et al., 2019). The SHINE trial had four groups: "IYCF, WASH, IYCF combined with WASH, and standard of care" (Humphrey et al., 2019; Pickering et al., 2019). The study populations of these studies were consenting pregnant women and their children, which were followed up between 18 to 24 months after their child was born (Humphrey et al., 2019; Luby et al., 2018; Null et al., 2018).

All these studies evaluated the effects of the WASH interventions on child stunting and childhood diarrhea. These studies observed these effects independently and combined with nutrition interventions. Unfortunately, all three trials found that there was no effect of the specific WASH interventions on child stunting and mixed effects on diarrhea (Humphrey et al., 2019; Luby et al., 2018; Null et al., 2018). The only study that showed a large relative risk reduction on diarrhea was WASH-B Bangladesh, and there was no effect observed in the Kenya (WASH-B Kenya) or Zimbabwe (SHINE) trials (Cumming et al., 2019; Pickering et al., 2019). These studies highlight some gaps occurring in WASH interventions that were thought to have a great effect on stunting and diarrhea, even when complemented with nutrition interventions (Pickering et al., 2019).

These RCTs have helped researchers explore gaps in current WASH interventions that must be addressed as the 2030 Sustainable Development Goal (SDG) end date comes closer (Wolf et al., 2018). Many of the gaps discussed could be addressed by incorporating the expanded One Health model. One gap discussed by researchers is that different environmental settings will require different WASH interventions, which may change over time in these locations. This is especially relevant in highly contaminated environments where there are a mix of different enteric pathogens that occur through different environmental pathways (Cumming et al., 2019). Researchers have also argued in the Cochrane Review that there is weak evidence of effects of WASH interventions on stunting in children (Dangour et al., 2013). The three RCTs align with the Cochrane Review by concluding there was no effect of WASH interventions on linear growth (Cumming et al., 2019). Many in the WASH sector believe that WASH interventions will improve linear growth among children by reducing enteric infections, but the

RCTs show that more research needs to be done to discover the underlying causes of stunting and most appropriate interventions to reduce stunting.

Another gap discussed by researchers is that many WASH interventions target the reduction of human fecal exposure. It is beneficial to have WASH interventions reduce human fecal exposure due to research showing that human feces contain diseases-causing bacteria, protozoa, viruses and parasites. However, there are other exposure sources and routes to harmful pathogens, such as animals and animal feces (Cumming et al., 2019). Researchers recommend more transformative WASH interventions that target all the possible exposure routes, not just human fecal exposure (Pickering et al., 2019). This gap could be better filled by incorporating the expanded One Health model that considers the animal and environmental pathways. To better understand the importance of considering animal and animal feces in transmission of harmful pathogens to humans, the next section will discuss the exposure to animals and animal feces in LMICs.

Exposure to Animals and Animal Feces in LMICs

In order to fill gaps in current WASH interventions discussed above, it's important to understand the burden of diseases from animal, their feces and the impact on human health. Unfortunately, research has been more focused on zoonotic transmission of respiratory and vector-borne pathogens instead of pathogens found in animal feces (Penakalapati et al., 2017). Often in low and middle-income countries (LMICs), animals are more present in the domestic environment, which causes people in these countries to have more exposure and contact with domestic animals (Delahoy et al., 2018). Animals are more present in the domestic environment in LMICs, because domestic animal ownership and middle and small-scale animal production is much more common in LMIC households than compared to high-income country households

(Penakalapati et al., 2017). These animals in LMICs contain a range of pathogens that are capable of infecting humans. These harmful pathogens are easily transmitted by the feces of animals, but the magnitude of risk they pose to human health is currently unquantified (Delahoy et al., 2018). Insufficient separation of animal feces in the environment has been found to be common in LMICs, which can directly lead to fecal-oral transmission of zoonotic diseases (Penakalapati et al., 2017). The people most at risk of experiencing severe lasting effects after zoonotic infections are children, pregnant women, and immunocompromised persons (Delahoy et al., 2018). It has also been shown that a lack of disposal of animal feces in domestic environments can facilitate fecal-oral transmission of zoonotic pathogens. This fecal-oral transmission of zoonotic pathogens can occur through direct contact with animal feces, fecal contaminated soil, fomites, food, or water sources (Delahoy et al., 2018).

Delahoy and colleagues (2018) conducted a systematic review of harmful zoonotic pathogens transmitted via animal feces in LMICs to understand pathogens that may meaningfully contribute to the global burden of disease in humans from animal feces in the hopes of assisting with intervention type and region prioritization (Delahoy et al., 2018). They focused on bacteria, protozoa, viruses, and helminths that were found in animal feces in domestic settings, cause illness in humans and provide a substantial contribution of disease burden (Delahoy et al., 2018). They narrowed these pathogens down to 15 and categorized them based on burden of disease and potential importance in transmission in animal feces in LMICs. This research highlights that there are many zoonotic pathogens that can be transmitted in animal feces with varying levels of importance in LMICs.

A systematic review that was conducted by Penakalapati et al. in 2017, looked at animal fecal exposure in Africa, Asia, South America, Oceania, and globally (Penakalapati et al., 2017)

and found that there was consistent evidence of a positive association between livestock and domestic poultry exposure and diarrheal illness. Even more alarming, this systematic review uncovered that animals that live in households increased the risk of diarrhea/infection of zoonotic pathogens in multiple studies (Penakalapati et al., 2017). It was also found that having animals living in households was negatively associated with child height-for-age Z-scores (HAZ) in Bangladesh and Ethiopia, which has impacts on overall child growth (Penakalapati et al., 2017). The risk of trachoma was also found to increase due to exposure to animals and animal feces (Penakalapati et al., 2017). This review identified six pathways of human exposure to animal feces: contamination of water sources, contamination of soil, contamination of food, contamination via flies, contamination of human hands, contamination of fomites. For contamination of human hands, the primary risk factor exposed was cohabitation of animals and humans in LMICs, which is a very common occurrence (Penakalapati et al., 2017). Overall, it appears that exposure to animal and animal feces have mixed effects on diarrhea, child growth, EED, STH infection and trachoma (Penakalapati et al., 2017). There is a need for future research to characterize human behaviors in the household that lead to animal fecal exposure, such as caregiver and child play practices.

Caregiver and Child Behavior/Play Practices with Animals in Household in LMICs

Exposure to animal feces among children and caregivers is a potential risk factor for zoonotic disease infections (Headey et al., 2017). More specifically, contamination can lead to an increase in exposure to animal feces by children and caregivers and thereby pose a risk for zoonotic disease. Infants and young children in LMICs ingest dirt and fecal matter through play objects, mouthing, soiled fingers, and household items (Rosenbaum et al., 2021). Fomites, such as everyday objects and toys, can be exposed to animals feces and lead to direct or indirect

human exposure by animal feces, exasperated by caregiver behaviors and child play practices (Penakalapati et al., 2017).

There are many ways children have contact with fomites. Two studies conducted in South Asia looked at environmental fecal contamination in rural households by examining toys that could come in direct contact with animal feces and be played with by children (Torondel et al., 2015; Vujcic et al., 2014). Specifically, one of these studies in rural India found that the average fecal contamination of toys was higher as the number of observed animal fecal piles increased in households (Torondel et al., 2015). The other study, in rural Bangladesh, discovered parallel findings in which there were higher fecal contamination of toys in households with animal feces present (Vujcic et al., 2014). It has also been found that some children are exposed to animal feces and animals by entering corrals and playing with poultry in Lima, Peru (Oberhelman et al., 2006). Furthermore, a study in rural Bangladesh discovered that E. coli was on 43% of child hands, which the researchers believe is from animal fecal exposure in the environment (Ercumen et al., 2017). This finding is similar to results of child hand contamination of E. coli from findings in a study in Tanzania and urban Bangladesh (Harris et al., 2016; Pickering et al., 2019). Lastly, there is increased exposure to animal feces from children being left to sit and/or play on homestead floors with limited monitoring by caregivers (Harris et al., 2016; Pickering et al., 2010). We must acknowledge all different ways that fomites pose risks for animal fecal exposure in children.

There is a link between caregiver behaviors in LMICs and increased animal fecal exposure for children (Penakalapati et al., 2017). Caregiver behaviors, such as cooking and feeding their children, can lead to an increase in animal fecal exposure via fomites. There are two studies, both in Peru, that examined this type of fecal contamination on cooking and feeding

utensils (Black et al., 1989; Ngure et al., 2013a). Black et al (1989) found that 35% of household objects, such as infant bottle nipples, feeding bottles, spoons, and can openers, had traces of *E. coli* (Black et al., 1989). The Ngure et al (2013) study found that 23% of households had infants' cups and spoons with positive *E. coli* cultures (Ngure et al., 2013a). It is hypothesized that indirect contamination of fomites occurred from these objects being dropped on contaminated surfaces or handled by contaminated hands of caregivers (Penakalapati et al., 2017). Another study in Bangladesh showed that there was an association between animal feces and complementary foods (Ercumen et al., 2017). Complementary foods are liquid or semisolid foods given in addition to breastfeeding to children after the age of 6 months to ensure adequate nutritional intake (Doza et al., 2018). The contamination of complementary foods was hypothesized to occur from caregivers not washing hands after handling animal feces before preparing food (Ercumen et al., 2017). To be more precise, an Ercumen et al (2017) study found E. coli in 58% of complementary foods (Ercumen et al., 2017). A different study in Bangladesh found that in a sample of children under 5 years of age, the odds of being stunted were double for children with caregivers that reported geophagy of fecal contaminated soils (Headey et al., 2017). Overall, multiple studies have reported that caregiver behaviors and child play practices lead to an increased risk of exposure to animal feces in the environment.

Impacts of Child Exposure to Animals and Animals Feces in LMICs

The first 5 years of life are a critical developmental period in children and are important to health, behavioral development, and growth (Verdeja et al., 2019). In some LMICs, children under five years have the highest risk of diarrheal illness due to poor management of animal fecal waste compared to any other age group (Harris et al., 2016; Lowenstein et al., 2020). The Global Burden of Disease 2015 report estimated that "approximately one-third of deaths among

children under five years due to diarrhea are attributed to pathogens that can be found in animal feces" (Wang et al., 2016). These reports show that the risk of illness due to zoonotic pathogens can have a huge impact on this critical developmental period in children. In general, animal feces have been found to play a significant role in transmission of zoonotic pathogens. Zoonotic disease transmission from animal feces is linked to acute and long-term clinical manifestations such as diarrhea, EED, growth outcomes, trachoma, and other health outcomes (Penakalapati et al., 2017). There are multiple studies that explore the impact exposure to animals and animal feces has on child health in LMICs.

Exposure to animals and animals feces can cause EED and effect growth outcomes in children in LMICs. Studies in Bangladesh and Malawi determined that exposure to animals and animal feces has the potential to increase the risk of EED, especially for children sleeping with animals or who have animal corrals in their bedrooms (George et al., 2015; Ordiz et al., 2016). Another study in Bangladesh identified that a high-risk factor for children with EED was close contact with animals (Harris et al., 2016). These studies support claims that EED is common among infants in LMICs and is a major pathway for stunting (Ngure et al., 2013). Additionally, a multi-country observational analysis in Bangladesh and Ethiopia revealed that presence of animal feces in households to negatively impact child HAZ (Headey et al., 2017). This multi-country observational analysis showed that there are "significant links between geophagy, animal exposure, EED and stunting" (Headey et al., 2017).

Exposure to animals and animal feces can lead to diarrhea in children in LMICs. A study in Lima, Peru found that living with chickens infected with zoonotic enteric pathogens caused an increased risk of diarrhea in children (Grados et al., 1988b). In Peruvian shantytowns, it was reported that children living in households with chickens had an increased risk of *Campylobacter*

infection, which is a common zoonotic enteric pathogen in children (Ercumen et al., 2017). In 2015, it was estimated that Campylobacter caused ~37,500 deaths from acute diarrhea, with most (30,900) of these deaths among children under five years. MAL-ED (The Etiology, Risk Factors and Interactions of Enteric Infections and Malnutrition and the Consequences for Child Health and Development study) identified Campylobacter as a major contributor to diarrhea in children under two years (Platts-Mills et al., 2015).

Many young children in LMICs are exposed further to animal feces by ingestion of animal feces and/or fecally contaminated soils, leading to further adverse health outcomes. Some studies in Bangladesh, Zimbabwe, and Peru observed that a large proportion of children injested soil and/or poultry feces directly (Headey et al., 2017). A study in Tanzania further found that having seen your child eat soil or chicken feces was positively associated with occurrence of diarrhea in epidemiological models (Verdeja et al., 2019).

All these studies discussed add to a growing body of evidence that child health and growth outcomes are influenced by exposure to animals and animal feces in LMICs. Although there are some benefits from livestock ownership, such as sources of income and nutrition for children, it's important to recognize the negative impact on child health and growth from animal, animal feces, and animal feces contaminated environments in LMICs (Kaur et al., 2017). After exploring data from an array of geographic regions and countries, it's apparent that there are similar findings on the negative impacts of animal and animal fecal exposure on children across LMICs in Africa, Asia, and South America. These findings include animal and animal fecal exposure leading to diarrheal illness, negatively impacting child HAZ scores (and other growth outcomes), and increasing EED and trachoma in children in LMICs.

Child Exposure to Animals and Animal Feces in Ecuador

There is some research that characterizes zoonotic disease transmission and adverse health outcomes in children in Ecuador. In general, it is estimated the diarrhea is a leading cause of mortality among children in LMICs of South America, such as Ecuador (Lowenstein et al., 2020). Specifically, it is estimated that each child under 5 years of age experiences at least four episodes of diarrhea each year in LMICs in South America (Lowenstein et al., 2020). Although there are adverse health outcomes, such as diarrhea, occurring in children in Ecuador, there are few studies conducted in Ecuador that explore this public health problem.

Only two studies were conducted in Ecuador that give context to zoonotic disease transmission for children. One of the studies aimed to look at the prevalence of seven zoonotic diseases in children and domestic animals in a semirural community in Ecuador (Vasco et al., 2016). The sampled households reported having the following animals, from most reported to least reported: chickens, guinea pigs, dogs, pigs, rabbits, cattle, cats, ducks, quails, sheep geese, and horses (Vasco et al., 2016). Similar to other studies discussed, this study found that chickens were a major source of *C. jejuni* and suggested zoonotic transmission of *C. jejuni* and aEPEC (Vasco et al., 2016). The main route of transmission of these zoonotic pathogens was hypothesized to be a result of child contact with animals or the contaminated environment. Another study in a semirural community of Quito, Ecuador concluded that domestic animal ownership did not significantly increase risk of zoonotic pathogen or diarrhea in children, but that children who regularly interact with animals may be at an increased risk for contracting zoonotic pathogens (Lowenstein et al., 2020). Unfortunately, neither of these studies provide insights on how animal and animal fecal exposure may impact child growth and health outcomes.

A prospective cohort study in Northwestern Ecuador (EcoMid) is currently exploring the conditions that impact enteric infections in children. More specifically, this study is investigating how environmental conditions affect child gut microbiome and enteric pathogen burden, short-term and long-term health outcomes associated with enteric pathogen infections, and how the gut microbiome responds/recovers from enteric pathogen infection (Lee et al., 2021). Since this study is ongoing, there are currently no published results, but it does open possibilities to explore exposure of animal, animal feces, and animal fecal-contaminated environments in Ecuador. EcoMid is the parent study under which this thesis is part of, allowing this thesis to provide important knowledge on child exposure to animals, animal feces and fecal contaminated environments across an urban-rural gradient in Ecuador.

Conclusion

There are many studies that provide evidence that LMICs have a high burden of domestic animals and zoonotic disease transmission, which impacts child health and growth outcomes negatively. Although there is generalizable data for all LMICs, Ecuador is one of many LMICs where there is little published research and data on this topic. Specifically, there are currently no published studies that explore child exposure to animals and animal feces, which may lead to zoonotic transmission of pathogens, in countries such as Ecuador.

This thesis aims to explore and provide additional insights on the if, how, and to what extent children under two years are exposed to animals, animal feces, and animal feces-contaminated environments in households with animals in Ecuador, and how exposure varies across communities. Using the lens of the expanded One Health model, these findings will lead to a better understanding of child exposure to animals, their feces, and their environments in Ecuador, which can guide future interventions, inlcuding transformative WASH interventions.

Chapter 3: Manuscript

Exposure to animals, animal feces and animal feces-contaminated environments for children under two years in households that own animals in Northwestern Ecuador: a qualitative research study

Nicholas Laramee[1], April M. Ballard[2], Bethany A. Caruso[1]
Hubert Department of Global Health, Emory University Rollins School of Public Health[1]
Gangarosa Department of Environmental Health, Emory University Rollins School of Public Health[2]

Abstract

Ecuador is estimated to have a high burden of child mortality from adverse health outcomes. Studies suggest that these negative health outcomes are occurring from child exposure to animal and animal feces. Existing research does not adequately explain if, how, to what extent and what conditions children are exposed to animals and animal feces in households that own domestic animals in Northwestern Ecuador.

Go-along in-depth interviews (IDIs) and a survey were utilized to explore child under 2 years of age exposure to animals, animal feces and fecal contaminated environments among children under 2 years of age, as well as interpersonal dynamics and influences on exposure in households that own animals. From February to April 2021, 32 IDIs and surveys were conducted in Spanish with mothers ages 19-47 years old along an urban-rural gradient. IDIs were completed with mothers of children ages 10-18 months old to gain insight on the following topics of interest: exposure inside the household, exposure outside but near the household, and exposure at non-household locations.

Participants highlighted exposure to animals and animal feces occurring inside the house, outside as well as near the household and even at non-household locations. These non-household locations included relatives, businesses, and neighbor's houses. The exposure to owned and stray domestic animals varied depending on locations, with most exposure occurring with domestic

animals and feces being from cats, dogs, and creole chickens. The most exposure for children appeared to occur inside households, but there was exposure still occurring at the other locations. Many participants revealed that interpersonal dynamics with family members, household characteristics and mother's behaviors influenced child exposure to animals, animal feces and fecal contaminated environments. Lastly, the participants also had varied reports of child exposure occurring across the urban-rural gradient in Northwestern Ecuador.

The findings of this study help explain the varied child exposure to animals and animal feces occurring inside households, outside but near households, and at non-household locations. The findings of this study serve can be used for a quantitative survey to better characterize child exposure risk to animals and their feces in Northwestern Ecuador. The findings of this study also have the potential to inform interventions to decrease exposure to pathogens from animals in Ecuador.

Introduction

Low- and middle-income countries (LMICs) have a high proportion of children with adverse infectious disease health outcomes such as diarrhea, environmental enteric dysfunction (EED), stunting and cognitive issues (Penakalapati et al., 2017). These negative health outcomes are leading to higher rates of deaths in LMICs, especially from diarrhea in children under 5 years of age according to the Global Burden of Disease 2015 report (Wang et al., 2016). To decrease the negative infectious disease health outcomes and high mortality in children of LMICs, global water, sanitation, and hygiene (WASH) interventions have been implemented for years to increase access to safe drinking water, sanitation services and access to handwashing facilities (World Health Organization & United Nations Children's Fund, 2021).

A systematic review and meta-analysis indicated that sanitation decreased diarrhea by 30-40% in children in LMICs (Freeman et al., 2017). However, several recent studies have shown that WASH interventions in LMICs have not found consistent evidence that these interventions are leading to a decrease of diarrhea incidence, decrease of fecal contamination in water storage, improvement on growth outcomes and malnutrition, or a decrease in soil-transmitted infections (Delahoy et al., 2018). WASH interventions do not disrupt all the pathways of infectious diseases and feces exposure for children (Delahoy et al., 2018), perhaps because many sanitation interventions focus heavily on the fecal-oral transmission pathway from human feces (Penakalapati et al., 2017). Although the human fecal-oral transmission pathway is essential in sanitation interventions, it's important to recognize that there is another chain of transmission occurring between animal feces and humans.

The Food and Agricultural Organization (FAO) reported in 2017 that domestic animals generate roughly 85% of the world's animal feces (Food and Agriculture Organization of the

United Nations (FAO), n.d.). The risk of exposure to animals and animal feces for adults and their children are even greater in LMICs than high-income countries (HICs), because domestic animal ownership and animal production is more common in rural and urban households in LMICs (Delahoy et al., 2018; Penakalapati et al., 2017). Disposal of animal feces at the household level is limited, allowing fecal-oral transmission of zoonotic pathogen through direct contact with animals, animal feces and/or fecal contaminated water, food and fomites (Delahoy et al., 2018). Additionally, some studies have linked child exposure to animals, animal feces, and animal feces-contaminated environments to adverse health outcomes in children in LMICs, such a diarrhea, EED and malnutrition (Delahoy et al., 2018). Although there is some understanding of how children are exposed to animals, animal feces and animal feces-contaminated environments in LMICs, there are still gaps that persist, especially in LMICs in South America.

Specifically, there is limited understanding of how children are exposure to animals, animal feces, and animal fecal contaminated environments in Ecuador. Few studies discuss zoonotic disease transmission occurring between children and domestic animals in Ecuador. A study in a semi-rural area found that the main transmission route for several zoonotic pathogens in humans is from direct contact with animals and/or the fecal contaminated environment (Vasco et al., 2016). Another study in Quito, Ecuador concluded that children may be at an increase for zoonotic infections if they regularly have contact with domestic animals (Lowenstein et al., 2020). Additional studies need to be conducted in urban and rural areas of Ecuador to better understand and characterize child exposure to animals, animal feces, and animal fecal-contaminated environments. The aims of this study were to: (1) describe if, how, to what extent, and under what conditions children under two years are exposed to animals, animal feces, and

animal feces-contaminated environments in households that own animals and (2) examine how exposure varies along the urban-rural gradient in Northwestern Ecuador.

Methods

Study Design

This study is part of an ongoing longitudinal cohort study, called *Ecomid,* which seeks to examine interactions between enteric infections and gut microbiome conditions, and how environmental conditions impact the development of the gut microbiome (Lee et al., 2021). Recognizing a gap, the mixed-methods *EcoMid AnEx* study was added to understand animal exposure influences on infant gut health across an urban-rural gradient in northwestern coastal Ecuador. This qualitative sub-study specifically explores exposure to animals, animal feces, and animal feces contaminated environments among a cohort of children under age two in households that own animals. Go along, semi-structured in-depth interviews (IDIs) of caregivers of the children were carried out in multiple study sites along the urban-rural gradient to understand what, how, and why children are exposed to animals and how that exposure varies by location.

Study Setting

This research took place in four study sites: (1) Esmeraldas, (2) Borbón, (3) rural villages near Borbón that are accessible by road (Rural Road communities) and (4) rural villages near Borbón that are only accessible by boat (Rural River communities). Esmeraldas is a city with roughly 150,000 inhabitants and represents the ‘urban’ site for this study. Borbón is located east of Esmeraldas and is an ‘intermediate’ town with a population of roughly 4,500 people (Lee et al., 2021). The other two study sites are rural villages ~1 hour southeast of Esmeraldas accessible by road and ~3 hours south of Borbón accessible by boat that each have a population around 400-920 people. These four study sites provide a high enteric pathogen transmission setting with similar social, cultural, and genetic factors (See Figure 1) (Lee et al., 2021).

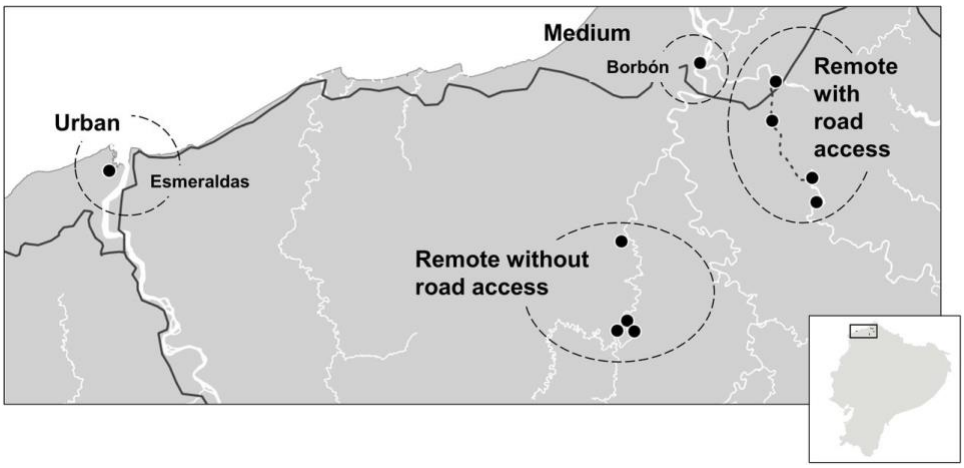

Figure 1: Study sites along the urban-rural gradient of the EcoMid study (Lee et al., 2021)

In-Depth Interviews

The team used a variation of semi-structured IDIs, referred to as go-along IDIs, since they are a combination of participant observation and interviewing in which the interviewer and participant inhabit the areas in which they are discussing (Garcia et al., 2012). More specifically, go-along interviews allow the interviewer to observe the interactions of the mother and infant with their animals and environment.

The IDI tool used as created by April Ballard, based on a conceptual framework she adapted, referred to as the Maternal and Animal-related Determinants of Child Health (MADCH) framework, from UNICEF's conceptual framework of undernutrition and the agriculture-nutrition pathways framework. This adapted conceptual framework shows potential causes and pathways of child exposure and child-nutrition linkages (See Figure 2).

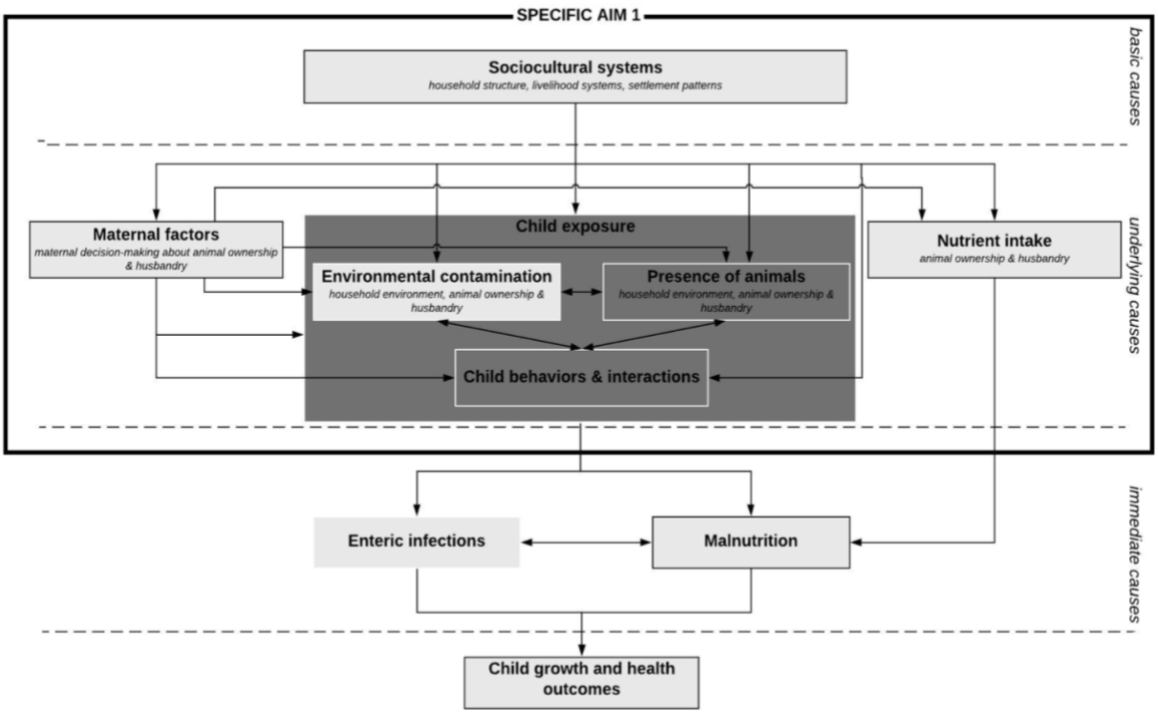

Figure 2: Maternal and Animal-related Determinants of Child Health (MADCH) framework created by April Ballard

The IDIs asked cohort mothers about conditions and behaviors that lead to child exposure to animals, animal feces, and animal feces-contaminated environments as well as reasons for and benefits of animal ownership, and animal-related household decision making. These IDIs included probes on details of animals, environmental conditions, behaviors and seasonality.

Sampling

This qualitative study recruited and enrolled mother-child dyads who are current participants in the parent Ecomid cohort study (n=32) from the following locations: Esmeraldas (n=11), Borbón (n=10), rural road communities (n=7) and rural river communities (n=4). Mothers were eligible if they were enrolled in the Ecomid cohort, had children between 6-18 months, gave informed consent, owned at least one animal, and if the sampling quota was not reached. This child age range was selected as an eligibility criterion because children became

more active and mobile during this time which left them more vulnerable to environmental exposures.

Participants were identified by Ecomid study staff through local research assistants and walkabouts in each community along the urban-rural gradient. More specifically, the local research assistants recommended participants who were then called to determine eligibility and availability. The sampling quota was reached if 10 households with animals in the specific community were interviewed.

Data collection

The research team engaged a female qualitative researcher from the study area who has worked in the area for more than 10 years. April Ballard trained her on the go-along IDI tools and process, which she carried out in Spanish from February to April 2021. The go-along IDIs were conducted with participants in the spaces they were discussing to produce richer narratives than sedentary interviews. Due to the ongoing COIVD-19 pandemic, adjustments were made for the go-along IDIs to be carried out in a comfortable and private space to allow the interviewer and participants to follow COVID-19 protocols, without compromising the go-along IDI format. Interviews lasted between 15-50 minutes and were audio-recorded, transcribed, de-identified, and translated from Spanish to English verbatim by two local Ecuadorian and cross-checked for accuracy by April Ballard. For participants who refused to be audio recorded (n=7), the interviewer took detailed notes during the interviews and created a transcript immediately afterwards based on the IDI guide. The interviewer also collected basic demographic information from participants through a short survey. Participants were given food items as an incentive for participating.

Data analysis

I conducted thematic analysis of the 32 IDIs using MAXQDA 2022 (VERBI Software, 2021). Study team members developed a codebook with deductive and inductive codes using IDI guides, transcripts, debriefing notes, and annotations. After developing the codebook, each transcript was double coded by two coders 10 at a time to facilitate cross-checking of coding and interpretation of data by each coder. After each 10 coded manuscripts, the following was addressed: coding agreement, and inter-rater reliability issues. Since meaning agreement was not always the goal, we did not rely on Cohen's kappa coefficient to assess inter-rater reliability issues. Any major differences in coding of the transcripts were resolved by the two coders. During the coding process, we assessed code saturation and meaning saturation (Hennink et al., 2017). Code saturation was achieved after coding five transcripts in this study, and meaning saturation was achieved after coding 10 transcripts.

After coding was completed, study team members queried and wrote memos on segments from transcripts for each code and intersections of codes. Specifically, the main codes of interest centered on exposure inside the house, exposure outside the house but in household compound, exposure in other households, space away from home, interpersonal dynamics, influences on exposure and limitations. I performed the query and memo process iteratively to explore, describe, compare, and explain key themes. The themes were categorized using the following criteria: themes that appeared as "all" (100% of interviews); "almost all" (90-99%); "most" (70-89%); "the majority" (50-69%); "several" (20-49%); and "a few" (less than 20%) (Sandelowski, 2001). Thick descriptions were developed of common themes and compared along the urban-rural gradient to answer the primary and secondary research questions.

I also conducted quantitative analysis of data from the surveys administered with participants. R studio was used to find the median and range of the following demographic information: age of mothers, age of children under 2 years of age, other children in households, other family members in houses, dogs owned, cats owned, creole chickens owned, production chickens owned, and pigs owned (*Rstudio Team*, 2022).

Ethics

Ethics approval was obtained from Emory University (IRB00101202) and Universidad San Franscisco de Quito Institutional (2018-022M) Review Boards. All participants provided written consent prior to data collection and were allowed to skip questions or end the interview at any time.

Results

Mothers participating in IDIs were 19 to 47 years old (median 29) with children ranging from 10-18 months old (median 14). Participants had 1-6 other children (median 3) and 3-13 other family members (median 5) in the household. Dogs and cats were the most commonly owned domestic animal type (dogs owned by 66% of households, median = 1) (cats owned by 66% of households, median = 1), followed by creole chickens (22% of households, median = 12), production chickens (9% of households, median = 4), and pigs (9% of households, median = 1.5).

Animal ownership varied across the urban-rural gradient in Northwestern Ecuador. Specifically, the table below (Table 1) shows that there are similar trends across the urban-rural gradient for cat ownership. Even though many households' own dogs in each eco-region, the urban area has the most households that own dogs. Creole chickens are most common in households in the rural and semi-rural areas, while production chickens are only owned by households in the semi-rural area. Similar to creole chicken ownership, pigs are only owned by households in rural and semi-rural areas.

Table 1: Number of Households that Own Specific Domestic Animals by Eco-Region

Animals Owned	Rural Road	Rural River	*Rural Total*	Semi-Rural	Urban	*Total Eco-Region*
Dogs	4	2	6	6	9	21
Cats	6	4	10	6	5	21
Creole Chickens	2	1	3	3	1	7
Production Chickens	0	0	0	3	0	3
Pigs	0	1	1	2	0	3
Total	12	8	20	20	15	55

Exposure Inside the House

Child exposure to animals, animal feces, and animal feces contaminated environments inside the house was the most commonly reported theme. Participants described exposure inside

the household as a product of six major pathways: presence of animals inside of household, fecal contamination inside the home, child exposure to feces or fecal contamination, direct child contact with animals, and fomites. These pathways appeared to vary across the urban-rural gradient, with the most participants in the urban area of Esmeraldas having highlighted the most frequent exposure inside the house.

Presence of animals and animal feces inside of household: The presence of animals and animal feces inside the house was a reoccurring discussion among participants. Presence of animals inside of the house was by far the most salient theme discussed for types of exposure inside the house among children under two years of age. Since all participants interviewed were part of a cohort of mothers that own animals, they reported having at least one animal spend time inside their households. The animals that participants reported coming inside their house were cats, dogs, and/or chickens, with cats being the most common.

Every participant that reported owning cat(s), except one participant, discussed that their cat spends time inside the house. Additionally, some cats from neighbors were reported by participants to enter their house on occasions. The most common places inside the house that the cats would reside were the living room and kitchen.

"P: The cats come in and out of the house. They get under the bed, under the dining table. The dog also enters and leaves, but passes more outside.
I: How often are there animals inside your house? How much time do the animals spend in your house?
The cats spend time in the kitchen, on the floor, under the dog, and the dog goes in and out. He spends more time outside the house."
-Participant 3007CW (age 32, Rural Roads)

A few participants justified having the cats inside the house to control the mice and/or rats. Seasonality and weather also motivated some participants to keep their cats inside more to avoid

them getting wet. Across the urban-rural gradient, participants reported similar accounts of cats inside the house.

For participants that reported owning dog(s), most explained that dogs were not allowed to spend time inside the household. Participants discussed deterring dogs from entering their households by throwing them out, yelling, closing the door, and pouring water on them. Most dogs reported to spend time inside the households were invited inside by family members to eat food or from doors being left open.

"I: Are there animals in your house in the morning? What type of animals are there in your house? Do they belong to you or to another person?
P: Yes, the cat spends time here, it is ours, the cat. Also the two dogs, but those do not stop here. They spend time in the street, they enter when the door is open."
-Participant 3005CW (age 26, Rural Roads)

Although most accounts were that dogs did not spend much time inside, a few participants reported that their owned dogs primarily stayed inside the household. Specifically, participants of the urban area of Esmeraldas most frequently reported that owned dogs primarily resided inside the household, followed by participants in the semi-rural area of Borbón. Lastly, some participants mentioned that stray or neighborhood dogs will come inside the house, but most are immediately kicked out. These dogs are either from relatives that live close by or neighbors.

Several participants owned creole and/or production chickens (n=10). Of those that own chickens, only a few reported that chickens spend time inside the house.

"The chicks, when they are hungry and they don't give them food, they come inside, so then one has to go outside and feed them"
-Participant 2016CW (age 31, Borbón)

Of the few participants that own chickens that come inside the house, those chickens are all creole chickens. None of the pigs owned by participants (n=3) were reported to come inside the household.

Overall, very few participants described domestic animal feces inside the house despite the frequent accounts of animal presence. The most reported animal feces inside the house were cat feces, which were only reported from participants living in Esmeraldas and Borbón. All cat feces inside were from participants who own cats. The next most reported animal feces inside the house were dog feces, with only two participants describing dog feces from dogs they own inside the house. Specifically, Esmeraldas had the only participants that reported dog feces inside the households. More participants in the urban areas reported cat and dog feces inside their households. The other animal feces sometimes found inside the house were chicken feces, either from owned chickens or neighborhood chickens. This was similarity reported across all sites. The participants discussed cleaning the feces with bleach, diesel, disinfectant, and/or chlorine, often with help from family members.

"I: In the afternoon, does the little dog defecate inside the house?
P: Go poop here in the afternoon, no.
I: And the cat?
P: No, he's almost never here…he left…a little.
I: Very little, okay, and in the afternoon if he does poop, how much, how often does he go?
P: The little dog?
I: Yes.
P: About three times a day, the little one.
I: What happens in those times that he poops inside the house?
P: When he goes in here, I clean it up, and use bleach and diesel on the floor where he went. I pour it and let it sit too."
-Participant 1002CW (age 30, Esmeraldas)

Few participants observed feces being brought inside the house by shoes/objects of family members. When other participants were probed further if feces were brough inside by shoes/objects, some reported that it was possible across all sites. Although many did not observe feces being brought inside the house via shoes, a few participants did report this occurring in their house.

"I: Perhaps other feces from the street?

P: Sometimes from the chicken, though
I: So, they do come inside (feces) And what happens when that occur?
P: We wash it over and we use bleach
I: I see, you wash it and you use bleach. And how does it come inside? So, it is definitely through the shoes, no?
P: Yes, yes"
-Participant 3001CW (age 22, Rural Road)

In addition, one participant did observe that animal feces are sometimes brought into the house by toys. A couple of participants discussed flooding occurring outside or inside the house during the rainy season.

Child exposures to animals, animal feces, and fomites: None of the participants spoke about their child having direct exposure to domestic animal feces or fecally contaminated objects/environments, but some did discuss their child having direct contact with animals, child floor play behavior, and child contact with fomites. The majority of participants reported that their child has some type of direct contact with domestic animals, either owned or not owned, inside the house. Participants reported similar observations on their child having direct contact with animals in the rural road community and the urban location of Esmeraldas.

Dogs were the most frequently animal (whether owned and not owned) that participants observed their children to have direct contact with. Most of these children had direct contact with dogs by hitting or jumping on them. It was more common for children to be allowed to play with small dogs (sometimes referred to as puppies) compared to adult or larger dogs. Most child contact with dogs was reported to have occurred during the morning and afternoon compared to the evening and night.

In contrast, there were very few observations made by participants of children under two years of age having contact with owned and not owned cats. Many of the participants explained that they would not allow their child to have contact with cats in fear of cats carrying diseases

and being dirty. For those that were allowed to play with cats, they mostly had direct contact by picking up the cats or touching them.

"The child has contact with the dog, he touches it, plays with the dog, touches its tail, its ears, not with the cat, the cat is bad"
-Participant 5002 (age 37, Rural Road)

There were zero observations by participants of children having contact with chickens or pigs inside the house by participants. Although most children were not reported to have direct contact to animals and/or animal feces outside, they may have indirect contact through family members. Most family members in the household, such as brothers, sisters, grandparents, and fathers, were reported to have contact with owned domestic animals and their feces.

Child floor behavior, such as children playing with toys/objects on the floor, could lead to exposure to feces or fecal contamination in households that own animals that defecate inside the house. The most common place that participants discussed their children playing on the floor was the living room.

"I: You are… so when the baby plays in the afternoon, does he also play on the floor?
P: Yes, on the floor.
I: Okay… in what environments is the baby in the afternoon, in what places?
P: Just here in the living room."
-Participant 1006CW (age 35, Esmeraldas)

The second most common place that the child of these participants exhibited floor play was the kitchen. Some of the children were not allowed to play on the floor by the participants. Along the urban-rural gradient, the frequency of descriptions among participants of their child exhibiting floor play behavior was similar.

Objects, which may be fomites, were frequently discussed by participants as a means for children under two years of age to potentially be exposed to animal feces inside the house. Almost all participants observed their child having contact with fomites inside the house and

most children were reported to play with toys, most commonly toy cars, balls and dolls. Other toys that the participant explained that their child played with included teddy bears, puzzles, legos, toys that rattle (*"marquitas"* and *"chinescos"*), dice, and other miscellaneous toys. Many of these children were also observed by participants to play with any objects they could find and grab.

"Her toys are the pins. She takes the pins out of the cartons and put them in again. She hardly plays with toys like dolls, cars, no. She spends time doing mischief here in the business, on the floor. She grabs the shelves, the chairs, and stops to reach what she can best and she throws everyone on the floor."
-Participant 5001CW (age 27, Rural Road)

The most common objects, which may be fomites, that children played with, that were not toys, were tv remote controls by throwing them or putting them in their mouths.

"I: Okay… Any other objects from the house that he maybe likes to play with? With any household objects?
P: What he hasn't really liked to touch is the remote controller, he throws it away.
I: Ahh, but he does pick it up?
P: Yes.
I: So what does he do with the controller?
P: He starts to push on the buttons, hahaha.
I: Okay… He wants to turn on the tv, change the channels?
P: I think he wants to change to the channels that he likes."
-Participant 9006CW (age 35, Rural River)

In addition, another common object that children had contact with were phones of their parents to watch videos and/or cartoons. There were other miscellaneous objects around the house, such as tablecloths, hats, screwdriver, and pencils, that the child was reported to have contact with, but these objects were not as frequently observed among all children. The living room was the most frequent location that fomite contact inside the house occurred. Fomite contact by children playing with or touching toys and objects was mostly during the morning and afternoon compared to night. Along the urban-rural gradient, participants reported similar observations on their child having direct contact with these fomites.

Exposure Outside the House in Household Compound:

Participants described exposure outside the house in the household compound as a product of six major pathways: presence of animals and animal feces outside of household, child exposure to feces or fecal contamination outside the home, direct child contact with animals outside the home, and fomites outside the home. These pathways appeared to vary across the urban-rural gradient.

Presence of animals and animal feces outside near household: Overall, dogs and cats were most observed outside of the house but inside the household compound by participants. Along the urban-rural gradient, a higher number of participants from rural areas reported domestic animals outside near the house. The most discussed animal observed outside of the house, but in the household compound, were domestic dogs. Most participants reported either owned or stray dogs spending time outside of their house. Dogs that are owned by the participants were commonly reported to stay predominantly outside of the house. These owned dogs spent most of their time on the patio, backyard, or entryway of the households. Besides the presence of owned dogs outside of the house, it was also often mentioned that stray and/or neighborhood dogs are seen walking up to or near the households. Most of these dogs spent a small amount of time outside the households. For the couple of households that reported owned dogs primarily residing inside the house, these dogs were still reported to go outside the household to defecate.

"I: Where do the dogs spend time?
P: There is one on the patio, and the other one at the front.
I: Oh okay, are they tied or are they free?
P: They are free, but I mean no, they don't go inside the house. The female dog goes up until the door, from the door not a step inside, and the one that is in the patio doesn't go in either, the cat is the one that goes inside the house."

The second most discussed animal to spend time outside near houses were cats. Most participants mentioned that cats are observed outside the households, most of them being owned by the participants. The cats that are owned by the participant were reported to frequently come inside and outside of the households. When cats spend time outside, the most common locations include the patio and roof.

"I: Okey, where is the cat at night?
P: In the place I already mentioned…Those cats usually stay on the roof of the house all night. You would see him on top of the washing machine for a little while, then he climbs to the roof where he stays. You could hear his noises from one place to the other"
-Participant 4002CW (age 21, Rural Road)

Similar to owned dogs inside the house, most of the owned cats inside the house would still go outside to defecate. Fewer participants observed stray and/or neighborhood cats coming up to the households.

Chickens were less common to be observed and reported by participants. All participants that owned production or creole chickens had them reside outside of the house but inside the household compound. A little over half of households that owned chickens lived in a hen house or enclosed area outside, but some chickens roamed freely outside on the patio, or it was not disclosed by the participant during the interview.

"…They do not go inside the house. They are kept in the yard, which is completely closed with block, the cement floor without smoothing and the zinc cover. The chickens are in a mesh cage, on plastic and a bad of sawdust."
-Participant 2004CW (age 31, Borbón)

Only a few participants recounted free roaming chickens from the neighborhood would come to the outside area of the households, but some did report this occurrence. Even though only two participants own pigs at their house, these two participants discussed that the pigs stay outside during the entirety of the day in a pigsty. One of the pigsties was reported to be on the side of the

house and the other pigsty underneath the house. The low number of participants owning creole chickens and pigs may be due family consumption discussed among participants, especially in the semi-rural area of Borbón. These participants explained that there was variability in creole chicken and pig ownership from family consumption of the creole chickens and pigs.

"P...Otherwise as we eat the others, they run out.
I: So then you get more.
P: No, I wait a while and then I start again, as my husband says, when I get a quarter of an hour, and start to buy again.
I: So when you feel the need to raise them to eat again?
P: Yes, because sometimes I don't have the means to start again."
Participant 1002CW (age 30, Esmeraldas)

One domestic animal that comes outside and close to the house of a participant is a horse owned by their neighbor.

Overall, fecal contamination in the environment outside of households but in household compounds was commonly observed and reported by participants across all sites. There were discussions of domestic feces from dogs, cats, chickens, pigs, and a horse outside but near the homes of participants. The most common domestic animal feces observed by participants outside of the house were dog feces. However, most participants that own dogs reported that the dogs would defecate outside but away from the home.

"I: Do your animals defecate inside your house? And other animals that are not yours?
P: No, they defecate in the street. I don't know where they do it, but they do not do it in the house
I: Where do they defecate inside your house?
P: The animals do not defecate inside the house.
I: How much stool is there normally? How many times do you find feces inside your home?
P: I really don't know, because as I said, neither cats nor dogs do their business near the house."
-Participant 3007CW (age 32, Rural Road)

Only a few participants discussed that their dogs defecated outside the house in the backyard, front, side, or patio of the house. In contrast, more participants reported neighborhood or stray dogs to defecate inside the household compound or near the house. Across all sites, participants

reported similar observations on the amount of dog feces outside near households. The dog feces found outside but near the household were reported by participants to be thrown out in an empty field, creek/river, trash, septic tank or covered with sand.

Cat feces appeared to be less present outside of houses according to participants. Most participants mentioned that they were unaware where their cats defecated and did not observe cat feces outside of the house. A consistent answer given by participants for the reason cat feces were not commonly observed outside the house was that cats cover their feces with sand. Another reason that participants explained for the lack of cat feces in environments outside near the house was that cats would defecate outside but far away from the house.

"I: Okay… and these animals of yours, in this case the dogs and the cats, they defecate? Where do they defecate?
P: They defecate far away from the house, and the cat digs, and covers."
-Participant 2018CW (age 21, Borbón)

Additionally, it was rare for participants to discuss that non-owned cats would defecate near the house, but there were a few accounts of cat defecation occurring by neighbors' cats in the sand outside and near households. Overall, more participants in rural areas reported cat feces outside near households. Although most participants did not have contact with cat feces outside, those that did reported cleaning it up with a shovel or broom to throw the feces in the trash or bury in the sand.

It was frequently reported by all participants who owned chickens and pigs that their feces were near and outside the house. Most reported that the chicken feces were found in the sawdust of the chicken house/pens or pigsties, but some participants mentioned the chicken feces could be found on the patio or at the entrance of their house. The chicken feces and/or sawdust

was always cleaned up with a shovel and thrown out according to participants, but it was rarely specified where the feces were thrown out.

"It is not known how much they make because the feces dry out and mix with the sawdust, and it is not eliminated daily. The feces are thrown away with the sawdust and this is changed one or two times a week."
-Participant 2004CW (age 31, Borbón)

There were some other methods of chicken fecal contamination of the environment outside of the house that were discussed by participants that were less common. For example, one participant mentioned that they let the rain wash away the chicken feces and another participant discussed chicken feces being used as fertilizer for plants outside but near the house.

"I: What do you do when the chickens defecate on the patio?
P: We pick it up, throw it in a spot for it to turn into fertilizer.
I: For fertilizer?
P: Yes, between some plants over there ??? we throw it.
I: So you have some plants back there?
P: Yes."
-Participant 1002CW (age 30, Esmeraldas)

The pig feces were cleaned out very differently from other domestic animal feces. The family throw water in the pigsties to wash the feces away. A participant noted horse feces would sometimes be outside of her house:

"I: Ok, ok, about what amount of feces do you find from horses?
P: From horses it is usually two daily or three because when they poop the owner comes down and cleans
I: The owner cleans himself?
P: Yes
I: When they are in a hurry, they leave it. When they go to work, they put down their load and they clean"
-Participant 9005CW (age 36, Rural River)

There were differences across sites reported by participants on the handling and cleaning of animal feces found outside. In rural communities, animal feces were reported to be through in an empty field (road communities) or in the river/creek/waterfall (river communities).

"I: Okay, and where do you throw away the feces lady ¿??? (name)?
P: In the creek.
I: That creek in where you throw away everything, does it maybe flow into the river?
P: Yes."
-Participant 9006CW (age 35, Rural River)

In urban areas, participants reported disposing of animal feces from outside in the trash, septic tank of covering it with sand.

"I: Since there are differences between cat and dog feces, is the way that you get rid of them or clean them up the same, or different for each, for the dog feces or the cat feces?
P: Yes, all the feces are put in the bag and thrown out separately, they don't get put in the same bag as the rest of the trash, and they're taken away when the trash collection comes."
-Participant 1012CW (age 20, Esmeraldas)

The urban-rural area of Borbón had participants mostly report similar disposal methods as the urban area, but one participant reported disposing of animal feces found outside in a field.

Child exposures to animals, their feces, and fomites: Discussions around children having direct contact with animals, child floor play behavior, and child contact with fomites were less apparent throughout interviews with participants. It was extremely uncommon for participants to report that their child had contact with animals outside the house. Only a few participants reported their child having direct contact with a dog outside the household, all except one being with a dog owned by the families. Participants highlighted that their child had direct contact with dogs outside by touching, playing, hugging, sitting, and lifting them. Even fewer participants described their child having direct contact with cats outside the house.

"I: Okay.. Any contact between the girl and the cat?
P: No, a little earlier just because he was standing at the door, but no, no, because the cat goes outside"
-Participant 2015CW (age 20, Borbón)

For participants that reported the child having direct contact with cats outside near the house, they highlighted that their child had contact with cats by touching, grabbing, and pulling their tails. It was more common for participants in rural communities to report their child having

contact with dogs or cats outside but near their house. The children did not seem to have any direct contact with chickens or pigs outside the house, but one participant did report that the child likes to throw rocks at their rooster.

Most children of the participants were not allowed to crawl and/or walk outside the house. Those that were allowed to walk or crawl outside had to have supervision by the participants or other family members, and most were only reported to walk.

"P: Yes, she tends to walk, when she has, when the door is open, she tends to go outside.
I: The girl, umm, does she generally spend time here inside, or does she play as well in the outside part of the house?
P: No, when I go with her, yes, I tend to take her out to take a walk for a bit.
I: To walk. Do you take her and bring her by grabbing her hand?
P: Yes."
-Participant 2013CW (age 29, Borbón)

The most common locations where the child was reported to walk outside the house were the patio and corridor. However, some participants did not specify the location outside the house where the child would crawl or walk. Along the urban-rural gradient, children under two years of age closer to the rural gradient were more commonly highlighted by participants to walk and crawl outside, but with supervision.

It was also very uncommon for participants to discuss their child having contact with objects, which may be fomites, outside the house. Only a few participants reported that their child played with objects and/or toys outside the house. The most played with toys by these children were balls, motorcycles, toy cars and hula-hoops. The objects played with by these children include glass and plastic. A few participants also highlighted that their child played with soil, dirt, rocks, and sticks outside the house. Most of these recounts of children playing with fomites outside near the house were made by participants in rural communities.

"Yes, she runs with her brothers. She wants to take everything she sees from the ground, stones, pieces of branches, sticks, but I don't let her because afterwards she puts her dirty hands in her mouth. When they finish playing, I take her up and wash her hands, arms, or bathe her."
-Participant 3005CW (age 26, Rural Road)

None of the children were reported to play in the rainwater or river outside near the households.

Exposure in Other Households and/or Space Away from Household

The majority of participants described exposure occurring in other houses and/or space away from the household as a product of a couple major pathways: presence of animals inside and outside non-household location, fecal contamination inside and outside another space, direct child contact with animals, their feces, and fomites. These pathways appeared to vary across the urban-rural gradient.

Presence of animals inside and outside other locations: It was very uncommon for participants to describe the presence of domestic animals inside or outside other households and/or space away from their households. Very few participants reported that other locations where their child spends time had cats or dogs inside. Participants were unanimous that there was no presence of chickens, pigs, or other animals inside other locations where their child spends time. However, several participants stated that dogs are outside in non-household locations where they spend time.

"P: She plays, the thing is that there at my mom's house she has like 9 dogs, doggies, and like four big ones, and has like two cats. So she over there, and my sister brings her up with the dogs, so she spends time with the dogs, playing with my nephews that are also there."
-Participant 1019CW (age 22, Esmeraldas)

Most of these dogs are owned by relatives but some are stray dogs. In comparison, only a few participants reported that there are cats or chickens outside of other locations where their child spends time. All these cats are owned by relatives and most of the chickens are also owned by relatives.

P: She has chickens and ducks there.
I: Ahh okay… and where does the dog spend time, inside or outside the house?
P: Outside the house.
-Participant 1017CW (age 19, Esmeraldas)

Most participants in urban areas reported these domestic animals (dogs, cats, and chickens) inside and outside non-household locations where their child spends time. However, it was more common for participants in rural areas to report that other locations where their child spends time had stray/neighborhood dogs pass by outside.

There were a couple domestic animals not frequently discussed outside of participant's households but were discussed outside other locations. One less discussed domestic animal described by a participant outside where she plays bingo at a neighbor's house is horses. These horses were told to be in the field outside this friend's house where the child spends time. There was also a report of a rabbit at a relative's house for one of the children, but it was unclear if the rabbit was inside, outside, or both.

Fecal contamination inside and outside: There appeared to be limited fecal contamination inside and other locations where the child of participants spend time. Inside of other locations, very few reports were made by participants that there was cat feces and/or dog feces inside.

"I: Okay… these animals, and the dog, do they defecate inside of the house?
P: The dog no, none of them both, the big ones no, but the small ones I imagine that in the cardboard then, in the cardboard."
-Participant 1019CW (age 22, Esmeraldas)

When there were descriptions of cat and/or dog feces inside these other locations, they were only at household locations of relatives and mostly in the urban area of Esmeraldas. There were no discussions of other domestic animal feces inside the other locations. In addition, a few

participants mentioned that it is possible that animal feces, such as chicken feces, are brought in by shoes into the other locations where their child spends time.

It was more frequently highlighted by participants that there was fecal contamination outside the other spaces. Several participants mentioned that dog feces are found outside of other locations, all being of relatives. Only a few participants discussed cat feces and chicken feces outside of other locations where their child spends time, all being relatives as well. The cat feces were usually found in the sand next to the house and the chicken feces were either found in the yard or patio. Most of the cat feces were in the urban area of Esmeraldas, but the chicken feces outside other locations were more common in rural areas.

"It was mentioned that chickens defecate in the yard, despite the fact that she had previously indicated that they did not; and when there is a lot of feces, they are scooped, which is cleaned in the morning and in the afternoon depending on whether there is a lot of chicken feces. She could not indicate what is a lot, but she mentioned that feces accumulate in some places in the yard near the house because chickens sometimes get out, and especially when the fighting cocks are loose."
-Participant 5001CW (age 27, Rural-Road)

There were reports of pig feces in the pigsty outside of a grandmother's house where the child spends time, but the pigsty is perceived by the participant as far away from the house. These reports of pig feces occurred in rural communities. Another participant mentioned that there are animal feces outside of a friend's house where she brings her child to play bingo but could not specify the type of animal feces. Overall, fecal contamination appears to be limited according to all participants inside and outside other locations across the urban-rural gradient.

Child exposures to animals, their feces, and fomites: Some participants discussed their child having direct contact with animals, child floor play behavior, and child contact with objects that may be fomites. Direct child contact with animals in non-household locations was rarely spoken about by participants. A few participants mentioned that their child had contact with

animals in non-household locations where they spend time across the rural-urban gradient. These children were only reported to have contact with cats either at non-household locations of relatives or businesses.

"I: Does your child have contact with other animals that are outside the house?
P: With his cousins' kitten when he goes over there, they have little kittens.
I: There in the house?
P: Yes, and he goes around grabbing them"
-Participant 1010CW (age 26, Esmeraldas)

Although no children were reported to have contact with other animals in non-household locations, one participant highlighted that their child throws rocks at the rooster of their grandma's house.

Few participants discussed that their child played on the floor at other locations where the child spent a significant amount of time. All these other locations where children were reported to play on the floor were households owned by relatives.

"I: So the child plays, does he play on the floor, or the activities that he does with his cousins or here in the house, do they play on the floor?
P: Yes."
-Participant 1010CW (age 26, Esmeraldas)

According to these participants, most of these children played on a rug or mat at these other locations. All these participants and their child lived closer to the urban gradient.

Child contact with objects, which may be fomites, at other locations was not heavily discussed by participants. Only a few participants mentioned that their child played with toys and/or objects in other locations. The most common toys that these children played with were dolls, legos, toy cars and balls. Some objects that these children played with at other locations were nail polish, soda, or *"anything else the child can grab"*. Most of these toys and/or objects were played with by these children inside the other locations according to participants. One

exception was from a participant who reported their child playing with leaves on the ground outside their grandma's house.

"I: Okay, can you describe how does the boy plays? Where exactly outside the house?
P: At my mom's, there they get inside the store to make a mess of everything they can from my mom, there is where he goes. If we leave from here, we go to my mom's, he goes directly there to play with all the leaves that he can throw there at my mom's."
-Participant 2016CW (age 31, Borbón)

Most children who were reported to play with toys/objects were located in the urban-rural town of Borbón. Additionally, several participants reported that their child had walked/crawled outside of the other locations, but this only occurred with supervision and primarily in rural communities. These children, sometime wearing flip flops, were observed walking and/or crawling in corridors, patios, sidewalks, and streets at some of these other locations.

"I: And her, while you go to the patio with the girl, she also walks there in the patio?
P: Yeah, with her flip flops."
-Participant 1017CW (age 19, Esmeraldas)

Discussion

An analysis of 32 go-along in-depth interviews (IDIs) conducted with mothers across four sites representing an urban-rural gradient in Northwestern Ecuador provided insight on if, how, to what extent, and under what conditions children under two years of age are exposed to animals, animal feces, and animal feces-contaminated environments. Overall, this analysis showed that children had exposure to animals, animal feces, and animal feces-contaminated environments inside their house, outside their house, and even in other households/spaces away from home. Interpersonal dynamics, household characteristics, and behaviors influenced exposure to animals, animal feces, and animal fecal-contaminated environments in household compounds and other spaces. Lastly, child exposure varied across the urban-rural gradient in Northwestern Ecuador.

The most exposure for children under two years of age in Northwestern Ecuador appeared to occur inside the house where the child resides, which is consistent with a study in a Peruvian slum that found that young children had a high amount of exposure to animals and their feces inside the household (Oberhelman et al., 2006). Additionally, this qualitative study found that children play and touch toys and/or objects, which may be fomites, on the floor inside their households, which has the potential to increase child exposure to animal feces, a finding consistent with other studies that concluded that children in LMICs are exposed indirectly to fomites through playing with objects on animal fecal contaminated surfaces (Penakalapati et al., 2017). In contrast to other literature, this study found that children that play on the floor are still exposed to animals and animal feces even when supervised by their mothers. Other studies observed exposure occurring for these children when playing on the floor unsupervised (Harris et al., 2016; Pickering et al., 2019). We found children in Ecuador to be exposed to cats, dogs, and

their feces inside the households, while other studies in LMICs focused more on child exposure to chicken and chicken feces inside households, which was not as common in this study (Black et al., 1989; Ngure et al., 2013b; Oberhelman et al., 2006).

The second most common location for child exposure to animals, animal feces, and fecal contaminated environments was outside of the house but in the household compound, which aligns with results from a study in rural central Bangladesh that concluded that most household compounds had domestic animals and animal feces present (Ercumen et al., 2017). The type of animals and their feces that children were exposed to in household compounds have some similarities when compared to other studies. We found that most children were exposed to owned and stray dogs outside households and in household compounds, which aligns with results from studies in Argentina and Malaysia (Acosta-Jamett et al., 2014; Tun et al., 2015), as well as a research in Peru, which showed that chickens and chicken feces were commonly outside household compounds, leading to possible exposure for children (Acosta-Jamett et al., 2014; Tun et al., 2015). Although many of the children were not reported to play on the floor outside or with objects, which may be fomites, outside in household compounds, there were some reports of this occurring on the patio or corrals, which is similar to other studies (Ercumen et al., 2017; Oberhelman et al., 2006).

The way animal feces were handled that were found inside or outside households could impact exposure for children. In rural communities, we found that it was common for animal feces to be thrown in a field nearby, in a river, or buried in the sand, all of which have the potential to lead to exposure for children due to environmental contamination. Similar to a study in rural India, Bauza et al study found that child feces were thrown away by mothers in open fields in rural areas (Bauza et al., 2020). In urban sites, it was more common for animal feces to

be thrown away in the trash or septic tank, which is similar to a study on human feces disposal in urban areas of Ethiopia (Beardsley et al., 2021). While both the Bauza et al study and Beardsley et al study refers to handling of human feces in LMICs, these studies are still relevant as a comparison since there are no currently published studies on animal feces disposal in rural areas of LMICs. This qualitative study also added some new perspectives on the effects of seasonality on animal-feces contaminated environments, not discussed by other studies, by showing that some mothers would let the rainwater wash away chicken feces outside, which could lead to additional exposure to environmental contamination.

Other locations, which are often not discussed in existing literature, but are where children under two years of age have exposure to animals, animal feces and feces-contaminated environments are non-household locations such as relatives and neighbors' houses and businesses. Some studies in LMICs have found that children are exposed to animals and animal feces outside of their households in public locations such as parks (Beardsley et al., 2021). Tthe scope of exposure occurring in these non-household locations may be limited, since the mother's perspective may have been restricted from not supervising the child at these locations. Despite this possible limitation, exposure to animal, animal feces, and feces contaminated environments is occurring at other locations beyond the household that have been thus far understudied.

Limitations and Strengths

There was unequal distribution of in-depth go-along interviews across the urban-rural gradient in Northwestern Ecuador. Most of the interviews were conducted in urban (n = 11) and semi-rural (n = 10) communities, while a few interviews were conducted in the rural road (n = 7) and rural river communities (n = 4). With fewer individuals representing the rural communities,

especially the rural river community, it is tough to identify true differences across the urban-rural gradient. Another limitation that arose from analyzing the interviews is that some participants mentioned not currently living in their house. This may impact discussions on exposure for children under two years of age in those households. Lastly, there was limited information on some topics that need further understanding.

There were some strengths to this study that are noteworthy. One strength of the qualitative study was the engagement of participants across four sites along the urban-rural gradient in Northwestern Ecuador. This allowed us to explore child animal exposure across geographic areas (urban-rural gradient), making findings more generalizable. Another strength of the methods of this study is that the interviews were double coded in MAXQDA. This strengthened the analysis and results by making the data more reliable and increasing the quality of the data (Church et al., 2019). Additionally, saturation was assessed to ensure that no further data was needed for analysis (Saunders et al., 2018). Lastly, having the interviewer conduct go-along IDIs with participants produced richer narratives than sedentary interviews by allowing the interview to cover topics more in depth and the interviewer to make observations of the mother and child in their environment with animals. These limitations and strengths should be recognized and taken into consideration when interpreting the results of this qualitative study.

Regardless of the limitations, this study contributes to new information on children under two years of age exposure to animals, animal feces and fecal contaminated environments across the urban-rural gradient in Northwestern Ecuador. Future research should include better characterizing child exposure risk to animals and animal feces in Ecuador, as this knowledge has the potential to decrease adverse health outcomes in children through transformative WASH interventions.

Chapter 4: Conclusions and Implications

The qualitative descriptions produced by this study provide insight on how, if, when and to what extent children under two years of age are exposed to animals, animal feces and fecal contaminated environments across the urban-rural gradient of Northwestern Ecuador. This insight helps us understand that many children under two years of age are exposed to animals, animal feces and animal fecal contaminated environments inside the house, outside the house and even in non-household locations. Furthermore, this study found that most child exposure occurs from cats, dogs and creole chickens depending on the location and urban-rural gradient.

The results from this qualitative study with mothers who own animals can be used to compare with a qualitative study with mothers who do not own animals along the same urban-rural gradient of Northwestern Ecuador. This qualitative comparison can better inform the similarities and differences between owning animals and not owning animals and the impact of animal ownership on exposure for children under two years of age. A quantitative survey, based on these qualitative results, will be constructed and administered throughout the urban-rural gradient in Northwestern Ecuador to quantitatively characterize child exposure risk to animals and animal feces. Overall, this qualitative study will contribute to understanding child exposure to animals and animal feces in Northwestern Ecuador and identify strategies to prevent exposure, possibly through implementation of public health interventions.

References

Acosta-Jamett, G., Weitzel, T., Boufana, B., Adones, C., Bahamonde, A., Abarca, K., Craig, P. S., & Reiter-Owona, I. (2014). Prevalence and Risk Factors for Echinococcal Infection in a Rural Area of Northern Chile: A Household-Based Cross-Sectional Study. *PLOS Neglected Tropical Diseases*, *8*(8), e3090. https://doi.org/10.1371/journal.pntd.0003090

Bauza, V., Majorin, F., Routray, P., Sclar, G. D., Caruso, B. A., & Clasen, T. (2020). Child feces management practices and fecal contamination: A cross-sectional study in rural Odisha, India. *The Science of the Total Environment*, *709*, 136169. https://doi.org/10.1016/j.scitotenv.2019.136169

Beardsley, R., Cronk, R., Tracy, W., Fleming, L., Ng'ambi, M., Tidwell, J. B., & Manga, M. (2021). Factors associated with safe child feces disposal in Ethiopia, India, and Zambia. *International Journal of Hygiene and Environmental Health*, *237*, 113832. https://doi.org/10.1016/j.ijheh.2021.113832

Black, R. E., Lopez De Roma, G., Brown, K. H., Bravo, N., Grados Bazalar, O., & Creed Kanashtro, H. (1989). Incidence and Etiology of Infantile Diarrhea and Major Routes of Transmission in Huascar, Peru. *American Journal of Epidemiology*, *129*(4), 785–799. https://doi.org/10.1093/oxfordjournals.aje.a115193

Chiodo, P., Basualdo, J., Ciarmela, L., Pezzani, B., Apezteguía, M., & Minvielle, M. (2006). Related factors to human toxocariasis in a rural community of Argentina. *Memórias Do Instituto Oswaldo Cruz*, *101*, 397–400. https://doi.org/10.1590/S0074-02762006000400009

Church, S. P., Dunn, M., & Prokopy, L. S. (2019). *Benefits to Qualitative Data Quality with Multiple Coders: Two Case Studies in Multi-coder Data Analysis*. 16.

Clasen, T., Boisson, S., Routray, P., Torondel, B., Bell, M., Cumming, O., Ensink, J., Freeman, M., Jenkins, M., Odagiri, M., Ray, S., Sinha, A., Suar, M., & Schmidt, W.-P. (2014). Effectiveness of a rural sanitation programme on diarrhoea, soil-transmitted helminth infection, and child malnutrition in Odisha, India: A cluster-randomised trial. *The Lancet Global Health*, *2*(11), e645–e653. https://doi.org/10.1016/S2214-109X(14)70307-9

Cumming, O., Arnold, B. F., Ban, R., Clasen, T., Esteves Mills, J., Freeman, M. C., Gordon, B., Guiteras, R., Howard, G., Hunter, P. R., Johnston, R. B., Pickering, A. J., Prendergast, A. J., Prüss-Ustün, A., Rosenboom, J. W., Spears, D., Sundberg, S., Wolf, J., Null, C., … Colford, J. M. (2019). The implications of three major new trials for the effect of water, sanitation and hygiene on childhood diarrhea and stunting: A consensus statement. *BMC Medicine*, *17*(1), 173. https://doi.org/10.1186/s12916-019-1410-x

Cunningham, A. A., Daszak, P., & Wood, J. L. N. (2017). One Health, emerging infectious diseases and wildlife: Two decades of progress? *Philosophical Transactions of the Royal Society B: Biological Sciences*, *372*(1725), 20160167. https://doi.org/10.1098/rstb.2016.0167

Dangour, A. D., Watson, L., Cumming, O., Boisson, S., Che, Y., Velleman, Y., Cavill, S., Allen, E., & Uauy, R. (2013). Interventions to improve water quality and supply, sanitation and hygiene practices, and their effects on the nutritional status of children. *Cochrane Database of Systematic Reviews*, *8*. https://doi.org/10.1002/14651858.CD009382.pub2

Delahoy, M. J., Wodnik, B., McAliley, L., Penakalapati, G., Swarthout, J., Freeman, M. C., & Levy, K. (2018). Pathogens transmitted in animal feces in low- and middle-income countries. *International Journal of Hygiene and Environmental Health*, *221*(4), 661–676. https://doi.org/10.1016/j.ijheh.2018.03.005

Doza, S., Jabeen Rahman, M., Islam, M. A., Kwong, L. H., Unicomb, L., Ercumen, A., Pickering, A. J., Parvez, S. M., Naser, A. M., Ashraf, S., Das, K. K., & Luby, S. P. (2018). Prevalence and Association of Escherichia coli and Diarrheagenic Escherichia coli in Stored Foods for Young Children and Flies Caught in the Same Households in Rural Bangladesh. *The American Journal of Tropical Medicine and Hygiene*, *98*(4), 1031–1038. https://doi.org/10.4269/ajtmh.17-0408

Ercumen, A., Pickering, A. J., Kwong, L. H., Arnold, B. F., Parvez, S. M., Alam, M., Sen, D., Islam, S., Kullmann, C., Chase, C., Ahmed, R., Unicomb, L., Luby, S. P., & Colford, J. M. (2017). Animal Feces Contribute to Domestic Fecal Contamination: Evidence from E. coli Measured in Water, Hands, Food, Flies, and Soil in Bangladesh. *Environmental Science & Technology*, *51*(15), 8725–8734. https://doi.org/10.1021/acs.est.7b01710

Food and Agriculture Organziation of the United Nations (FAO). (n.d.). *FAOSTAT*. Fao.Org. Retrieved April 6, 2022, from https://www.fao.org/faostat/en/#home

Freeman, M. C., Garn, J. V., Sclar, G. D., Boisson, S., Medlicott, K., Alexander, K. T., Penakalapati, G., Anderson, D., Mahtani, A. G., Grimes, J. E. T., Rehfuess, E. A., & Clasen, T. F. (2017). The impact of sanitation on infectious disease and nutritional status: A systematic review and meta-analysis. *International Journal of Hygiene and Environmental Health*, *220*(6), 928–949. https://doi.org/10.1016/j.ijheh.2017.05.007

Garcia, C. M., Eisenberg, M. E., Frerich, E. A., Lechner, K. E., & Lust, K. (2012). Conducting Go-Along Interviews to Understand Context and Promote Health. *Qualitative Health Research*, *22*(10), 1395–1403. https://doi.org/10.1177/1049732312452936

George, C. M., Oldja, L., Biswas, S. K., Perin, J., Lee, G. O., Ahmed, S., Haque, R., Bradley Sack, R., Parvin, T., Azmi, I. J., Bhuyian, S. I., Talukder, K. A., & Faruque, A. G. (2015). Fecal Markers of Environmental Enteropathy Are Associated with Animal Exposure and Caregiver Hygiene in Bangladesh. *The American Journal of Tropical Medicine and Hygiene*, *93*(2), 269–275. https://doi.org/10.4269/ajtmh.14-0694

Grados, O., Bravo, N., Black, R. E., & Butzler, J. P. (1988a). Paediatric campylobacter diarrhoea from household exposure to live chickens in Lima, Peru. *Bulletin of the World Health Organization*, *66*(3), 369–374.

Grados, O., Bravo, N., Black, R. E., & Butzler, J. P. (1988b). Paediatric campylobacter diarrhoea from household exposure to live chickens in Lima, Peru. *Bulletin of the World Health Organization*, *66*(3), 369–374.

Harris, A. R., Pickering, A. J., Harris, M., Doza, S., Islam, M. S., Unicomb, L., Luby, S., Davis, J., & Boehm, A. B. (2016). Ruminants Contribute Fecal Contamination to the Urban Household Environment in Dhaka, Bangladesh. *Environmental Science & Technology*, *50*(9), 4642–4649. https://doi.org/10.1021/acs.est.5b06282

Headey, D., Nguyen, P., Kim, S., Rawat, R., Ruel, M., & Menon, P. (2017). Is Exposure to Animal Feces Harmful to Child Nutrition and Health Outcomes? A Multicountry Observational Analysis. *The American Journal of Tropical Medicine and Hygiene*, *96*(4), 961–969. https://doi.org/10.4269/ajtmh.16-0270

Hennink, M. M., Kaiser, B. N., & Marconi, V. C. (2017). Code Saturation Versus Meaning Saturation: How Many Interviews Are Enough? *Qualitative Health Research*, *27*(4), 591–608. https://doi.org/10.1177/1049732316665344

Humphrey, J. H., Mbuya, M. N. N., Ntozini, R., Moulton, L. H., Stoltzfus, R. J., Tavengwa, N. V., Mutasa, K., Majo, F., Mutasa, B., Mangwadu, G., Chasokela, C. M., Chigumira, A., Chasekwa, B., Smith, L. E., Tielsch, J. M., Jones, A. D., Manges, A. R., Maluccio, J. A., Prendergast, A. J., … Makoni, T. (2019). Independent and combined effects of improved water, sanitation, and hygiene, and improved complementary feeding, on child stunting and anaemia in rural Zimbabwe: A cluster-randomised trial. *The Lancet Global Health*, *7*(1), e132–e147. https://doi.org/10.1016/S2214-109X(18)30374-7

Jones, K. E., Patel, N. G., Levy, M. A., Storeygard, A., Balk, D., Gittleman, J. L., & Daszak, P. (2008). Global trends in emerging infectious diseases. *Nature*, *451*(7181), 990–993. https://doi.org/10.1038/nature06536

Kaur, M., Graham, J. P., & Eisenberg, J. N. S. (2017). Livestock Ownership among Rural Households and Child Morbidity and Mortality: An Analysis of Demographic Health Survey Data from 30 Sub-Saharan African Countries (2005–2015). *The American Journal of Tropical Medicine and Hygiene*, *96*(3), 741–748. https://doi.org/10.4269/ajtmh.16-0664

Lee, G. O., Eisenberg, J. N. S., Uruchima, J., Vasco, G., Smith, S. M., Van Engen, A., Victor, C., Reynolds, E., MacKay, R., Jesser, K. J., Castro, N., Calvopiña, M., Konstantinidis, K. T., Cevallos, W., Trueba, G., & Levy, K. (2021). Gut microbiome, enteric infections and child

growth across a rural–urban gradient: Protocol for the ECoMiD prospective cohort study. *BMJ Open*, *11*(10), e046241. https://doi.org/10.1136/bmjopen-2020-046241

Lowenstein, C., Vasco, K., Sarzosa, S., Salinas, L., Torres, A., Perry, M. J., Simmens, S. J., Trueba, G., Eisenberg, J. N. S., & Graham, J. P. (2020). Determinants of Childhood Zoonotic Enteric Infections in a Semirural Community of Quito, Ecuador. *The American Journal of Tropical Medicine and Hygiene*, *102*(6), 1269–1278. https://doi.org/10.4269/ajtmh.19-0690

Luby, S. P., Rahman, M., Arnold, B. F., Unicomb, L., Ashraf, S., Winch, P. J., Stewart, C. P., Begum, F., Hussain, F., Benjamin-Chung, J., Leontsini, E., Naser, A. M., Parvez, S. M., Hubbard, A. E., Lin, A., Nizame, F. A., Jannat, K., Ercumen, A., Ram, P. K., … Colford, J. M. (2018). Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural Bangladesh: A cluster randomised controlled trial. *The Lancet Global Health*, *6*(3), e302–e315. https://doi.org/10.1016/S2214-109X(17)30490-4

Marquis, G. S., Ventura, G., Gilman, R. H., Porras, E., Miranda, E., Carbajal, L., & Pentafiel, M. (1990). Fecal contamination of shanty town toddlers in households with non-corralled poultry, Lima, Peru. *American Journal of Public Health*, *80*(2), 146–149.

Ngure, F. M., Humphrey, J. H., Mbuya, M. N. N., Majo, F., Mutasa, K., Govha, M., Mazarura, E., Chasekwa, B., Prendergast, A. J., Curtis, V., Boor, K. J., & Stoltzfus, R. J. (2013a). Formative Research on Hygiene Behaviors and Geophagy among Infants and Young Children and Implications of Exposure to Fecal Bacteria. *The American Journal of Tropical Medicine and Hygiene*, *89*(4), 709–716. https://doi.org/10.4269/ajtmh.12-0568

Ngure, F. M., Humphrey, J. H., Mbuya, M. N. N., Majo, F., Mutasa, K., Govha, M., Mazarura, E., Chasekwa, B., Prendergast, A. J., Curtis, V., Boor, K. J., & Stoltzfus, R. J. (2013b). Formative Research on Hygiene Behaviors and Geophagy among Infants and Young Children and Implications of Exposure to Fecal Bacteria. *The American Journal of Tropical Medicine and Hygiene*, *89*(4), 709–716. https://doi.org/10.4269/ajtmh.12-0568

Null, C., Stewart, C. P., Pickering, A. J., Dentz, H. N., Arnold, B. F., Arnold, C. D., Benjamin-Chung, J., Clasen, T., Dewey, K. G., Fernald, L. C. H., Hubbard, A. E., Kariger, P., Lin, A., Luby, S. P., Mertens, A., Njenga, S. M., Nyambane, G., Ram, P. K., & Colford, J. M. (2018). Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural Kenya: A cluster-randomised controlled trial. *The Lancet Global Health*, *6*(3), e316–e329. https://doi.org/10.1016/S2214-109X(18)30005-6

Oberhelman, R. A., Gilman, R. H., Sheen, P., Cordova, J., Zimic, M., Cabrera, L., Meza, R., & Perez, J. (2006). AN INTERVENTION-CONTROL STUDY OF CORRALLING OF FREE-RANGING CHICKENS TO CONTROL CAMPYLOBACTER INFECTIONS AMONG CHILDREN IN A PERUVIAN PERIURBAN SHANTYTOWN. *The American Journal of Tropical Medicine and Hygiene*, *74*(6), 1054–1059. https://doi.org/10.4269/ajtmh.2006.74.1054

Ordiz, M. I., Shaikh, N., Trehan, I., Maleta, K., Stauber, J., Shulman, R., Devaraj, S., Tarr, P. I., & Manary, M. J. (2016). Environmental Enteric Dysfunction Is Associated With Poor Linear Growth and Can Be Identified by Host Fecal mRNAs. *Journal of Pediatric Gastroenterology and Nutrition*, *63*(5), 453–459. https://doi.org/10.1097/MPG.0000000000001315

Penakalapati, G., Swarthout, J., Delahoy, M. J., McAliley, L., Wodnik, B., Levy, K., & Freeman, M. C. (2017). Exposure to Animal Feces and Human Health: A Systematic Review and Proposed Research Priorities. *Environmental Science & Technology*, *51*(20), 11537–11552. https://doi.org/10.1021/acs.est.7b02811

Pickering, A. J., Davis, J., Walters, S. P., Horak, H. M., Keymer, D. P., Mushi, D., Strickfaden, R., Chynoweth, J. S., Liu, J., Blum, A., Rogers, K., & Boehm, A. B. (2010). Hands, Water, and Health: Fecal Contamination in Tanzanian Communities with Improved, Non-Networked Water Supplies. *Environmental Science & Technology*, *44*(9), 3267–3272. https://doi.org/10.1021/es903524m

Pickering, A. J., Null, C., Winch, P. J., Mangwadu, G., Arnold, B. F., Prendergast, A. J., Njenga, S. M., Rahman, M., Ntozini, R., Benjamin-Chung, J., Stewart, C. P., Huda, T. M. N., Moulton, L. H., Colford, J. M., Luby, S. P., & Humphrey, J. H. (2019). The WASH Benefits and SHINE trials: Interpretation of WASH intervention effects on linear growth and diarrhoea. *The Lancet Global Health*, *7*(8), e1139–e1146. https://doi.org/10.1016/S2214-109X(19)30268-2

Platts-Mills, J. A., Babji, S., Bodhidatta, L., Gratz, J., Haque, R., Havt, A., McCormick, B. J., McGrath, M., Olortegui, M. P., Samie, A., Shakoor, S., Mondal, D., Lima, I. F., Hariraju, D., Rayamajhi, B. B., Qureshi, S., Kabir, F., Yori, P. P., Mufamadi, B., … Houpt, E. R. (2015). Pathogen-specific burdens of community diarrhoea in developing countries: A multisite birth cohort study (MAL-ED). *The Lancet Global Health*, *3*(9), e564–e575. https://doi.org/10.1016/S2214-109X(15)00151-5

Rosenbaum, J., Tenaw, E., Clemmer, R., Israel, M., & Albert, J. (2021). Exploring the Use and Appeal of Playpens to Protect Infants from Exposure to Animals, Animal Feces, and Dirt in Rural Ethiopia. *The American Journal of Tropical Medicine and Hygiene*, *104*(1), 346–356. https://doi.org/10.4269/ajtmh.20-0445

Rstudio Team (RStudio: Integrated Development for R). (2022). [Computer software]. RStudio, PBC.

Sandelowski, M. (2001). Real qualitative researchers do not count: The use of numbers in qualitative research. *Research in Nursing & Health*, *24*(3), 230–240. https://doi.org/10.1002/nur.1025

Saunders, B., Sim, J., Kingstone, T., Baker, S., Waterfield, J., Bartlam, B., Burroughs, H., & Jinks, C. (2018). Saturation in qualitative research: Exploring its conceptualization and operationalization. *Quality & Quantity*, *52*(4), 1893–1907. https://doi.org/10.1007/s11135-017-0574-8

Torondel, B., Gyekye-Aboagye, Y., Routray, P., Boisson, S., Schimdt, W., & Clasen, T. (2015). Laboratory development and field testing of sentinel toys to assess environmental faecal exposure of young children in rural India. *Transactions of The Royal Society of Tropical Medicine and Hygiene*, *109*(6), 386–392. https://doi.org/10.1093/trstmh/trv023

Tun, S., Ithoi, I., Mahmud, R., Samsudin, N. I., Heng, C. K., & Ling, L. Y. (2015). Detection of Helminth Eggs and Identification of Hookworm Species in Stray Cats, Dogs and Soil from Klang Valley, Malaysia. *PLOS ONE*, *10*(12), e0142231. https://doi.org/10.1371/journal.pone.0142231

Vasco, K., Graham, J. P., & Trueba, G. (2016). Detection of Zoonotic Enteropathogens in Children and Domestic Animals in a Semirural Community in Ecuador. *Applied and Environmental Microbiology*, *82*(14), 4218–4224. https://doi.org/10.1128/AEM.00795-16

VERBI Software. (2021). [MAXQDA 2022]. VERBI Software. maxqda.com

Verdeja, M., Thomas, K., Dorsan, G., Hawks, M., Dearden, K., Stroupe, N., Hoj, T., West, J., Crookston, B., Ezekial, M., & Hall, C. (2019). Water, Sanitation, and Hygiene Factors Associated with Child Illness in Tanzania. *Health*, *11*(6), 827–840. https://doi.org/10.4236/health.2019.116066

Vujcic, J., Ram, P. K., Hussain, F., Unicomb, L., Gope, P. S., Abedin, J., Mahmud, Z. H., Sirajul Islam, M., & Luby, S. P. (2014). Toys and toilets: Cross-sectional study using children's toys to evaluate environmental faecal contamination in rural Bangladeshi households with different sanitation facilities and practices. *Tropical Medicine & International Health*, *19*(5), 528–536. https://doi.org/10.1111/tmi.12292

Wang, H., Naghavi, M., Allen, C., Barber, R. M., Bhutta, Z. A., Carter, A., Casey, D. C., Charlson, F. J., Chen, A. Z., Coates, M. M., Coggeshall, M., Dandona, L., Dicker, D. J., Erskine, H. E., Ferrari, A. J., Fitzmaurice, C., Foreman, K., Forouzanfar, M. H., Fraser, M. S., … Murray, C. J. L. (2016). Global, regional, and national life expectancy, all-cause mortality, and cause-specific mortality for 249 causes of death, 1980–2015: A systematic analysis for the Global Burden of Disease Study 2015. *The Lancet*, *388*(10053), 1459–1544. https://doi.org/10.1016/S0140-6736(16)31012-1

Woldehanna, S., & Zimicki, S. (2015). An expanded One Health model: Integrating social science and One Health to inform study of the human-animal interface. *Social Science & Medicine (1982)*, *129*, 87–95. https://doi.org/10.1016/j.socscimed.2014.10.059

Wolf, J., Hunter, P. R., Freeman, M. C., Cumming, O., Clasen, T., Bartram, J., Higgins, J. P. T., Johnston, R., Medlicott, K., Boisson, S., & Prüss-Ustün, A. (2018). Impact of drinking water, sanitation and handwashing with soap on childhood diarrhoeal disease: Updated meta-analysis and meta-regression. *Tropical Medicine & International Health*, *23*(5), 508–525. https://doi.org/10.1111/tmi.13051

World Health Organization, & United Nations Children's Fund. (2021). *Progress on household drinking water, sanitation and hygiene 2000-2020: Five years into the SDGs*.

Appendix

Table 1: Domestic Animals Owned in each Household of Child

Table 1: Domestic Animals Owned in each Household of Child by Participant ID							
Participant ID	Eco-region	Dogs	Cats	Criollo Chickens	Production Chickens	Pigs	Total Animals
3001CW	Rural Road	5	0	20	0	0	25
3003CW	Rural Road	0	1	0	0	0	1
3005CW	Rural Road	2	1	0	0	0	3
3007CW	Rural Road	1	2	0	0	0	3
4002CW	Rural Road	0	1	0	0	0	1
5001CW	Rural Road	0	1	20	0	0	21
5002CW	Rural Road	1	1	0	0	0	2
Rural Road Total		**9**	**7**	**40**	**0**	**0**	**56**
7002CW	Rural River	1	1	0	0	0	2
9003CW	Rural River	0	1	0	0	0	1
9005CW	Rural River	0	1	0	0	0	1
9006CW	Rural River	4	4	4	0	2	16
Rural River Total		**5**	**7**	**4**	**0**	**2**	**20**
Rural Total		**14**	**14**	**44**	**0**	**2**	**76**
2001CW	Sem-rural	1	0	6	0	0	7
2004CW	Sem-rural	0	0	0	3	0	3
2007CW	Sem-rural	0	1	0	0	0	1
2008CW	Sem-rural	1	1	0	0	0	2
2012CW	Sem-rural	0	0	0	4	0	4
2013CW	Sem-rural	0	1	0	20	0	21
2015CW	Sem-rural	2	1	0	0	many	>3
2016CW	Sem-rural	1	1	15	0	0	17
2018CW	Sem-rural	2	3	2	0	1	8
2019CW	Sem-rural	2	0	0	0	0	2
Semi-Rural Total		**9**	**8**	**23**	**27**	**many**	**>67**
1001CW	Urban	1	0	0	0	0	1
1002CW	Urban	4	1	9	0	0	14
1006CW	Urban	0	1	0	0	0	1
1007CW	Urban	2	2	0	0	0	4
1010CW	Urban	1	0	0	0	0	1
1011CW	Urban	1	0	0	0	0	1
1012CW	Urban	2	1	0	0	0	3
1013CW	Urban	1	0	0	0	0	1
1015CW	Urban	1	0	0	0	0	1
1017CW	Urban	1	0	0	0	0	1
1019CW	Urban	0	1	0	0	0	1
Urban Total		**14**	**6**	**9**	**0**	**0**	**29**

Table 2: Demographic and Household Characteristics

Table 2: Demographic and Household Characteristics									
Participant ID	Mom age	Child age	Child sex	Others HH	Kids HH	Ethnicity	Floor	Roof	Walls
3001CW	22	13	female	4	3	Afro-Ecuadorian	other	metal/zinc	cement blocks
3003CW	35	17	female	5	3	Afro-Ecuadorian	ceramic tiles	other	cement blocks
3005CW	26	16	female	5	3	Afro-Ecuadorian	cement	other	cement blocks
3007CW	32	17	female	4	3	Mestizo	wooden boards	metal/zinc	wooden board/wooden shingles or tiles
4002CW	21	10	female	6	3	Afro-Ecuadorian	cement	metal/zinc	cement blocks
5001CW	27	12	female	4	2	Afro-Ecuadorian	cement	metal/zinc	cement blocks
5002CW	37	13	male	6	4	Afro-Ecuadorian	ceramic tiles	metal/zinc	cement blocks
7002CW	38	14	male	8	2	Afro-Ecuadorian	wooden boards	metal/zinc	wooden board/wooden shingles or tiles
9003CW	22	18	male	4	2	Mestizo	cement	metal/zinc	cement blocks
9005CW	36	13	female	7	2	Afro-Ecuadorian	cement	metal/zinc	cement blocks
9006CW	35	15	male	6	4	Afro-Ecuadorian	wooden boards	metal/zinc	wooden board/wooden shingles or tiles
2001CW	28	14	male	3	1	Mestizo	wooden boards	metal/zinc	wooden board/wooden shingles or tiles
2004CW	31	11	male	5	3	Afro-Ecuadorian	ceramic tiles	metal/zinc	cement blocks
2007CW	21	14	female	5	1	Afro-Ecuadorian	ceramic tiles	metal/zinc	cement blocks
2008CW	35	11	male	7	4	Afro-Ecuadorian	cement	metal/zinc	cement blocks
2012CW	35	14	female	4	2	Afro-Ecuadorian	wooden boards	metal/zinc	cement blocks
2013CW	29	15	female	7	3	Afro-Ecuadorian	ceramic tiles	metal/zinc	cement blocks
2015CW	20	12	female	10	3	Afro-Ecuadorian	ceramic tiles	metal/zinc	cement blocks
2016CW	31	15	male	5	3	Afro-Ecuadorian	ceramic tiles	metal/zinc	cement blocks
2018CW	21	13	male	13	3	Afro-Ecuadorian	wooden boards	metal/zinc	wooden board/wooden

									shingles or tiles
2019CW	25	18	female	6	4	Afro-Ecuadorian	cement	metal/zinc	cement blocks
1001CW	29	18	male	6	3	Afro-Ecuadorian	ceramic tiles	metal/zinc	cement
1002CW	30	10	male	6	4	Afro-Ecuadorian	cement	metal/zinc	bricks
1006CW	35	16	male	7	4	Afro-Ecuadorian	wooden boards	metal/zinc	cement blocks
1007CW	28	17	male	4	2	Afro-Ecuadorian	ceramic tiles	metal/zinc	cement blocks
1010CW	26	13	male	4	1	Afro-Ecuadorian	cement	metal/zinc	cement blocks
1011CW	29	12	female	5	3	Afro-Ecuadorian	cement	metal/zinc	cement blocks
1012CW	20	11	female	3	1	Mestizo	cement	metal/zinc	cement blocks
1013CW	47	16	male	8	6	Afro-Ecuadorian	ceramic tiles	cement	bricks
1015CW	33	11	male	7	5	Afro-Ecuadorian	cement	metal/zinc	cement blocks
1017CW	19	15	female	4	1	Afro-Ecuadorian	cement	metal/zinc	cement blocks
1019CW	22	17	female	3	1	Afro-Ecuadorian	cement	metal/zinc	cement blocks

Momage = mothers age (years), Childage = child under 2 age (months), OthersHH = other people living in household, KidsHH = other children living in household, Floor = material of household floor, Roof = material of household roof, Walls = material of household walls