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IFPRI Discussion Paper 01665

July 2017

Assessing the Health and Nutrition Risks of Smallholder Poultry Production in Burkina Faso

Insights from Formative Research

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ABSTRACT

The *Soutenir l'Exploitation Familiale pour Lancer l'Élevage des Volailles et Valoriser l'Économie Rurale* (SELEVER) study is designed to evaluate the impact of an integrated agriculture-nutrition intervention package (including poultry value chain development; women's empowerment activities; and a behavior change communications strategy to promote improved diets and feeding, care, and hygiene practices) on the diets, health, and nutritional status of women and children in Burkina Faso.
The aim of the formative research was to assess the need for an intensive water, sanitation, and hygiene (WASH) and poultry-related hygiene component that could be rolled out alongside the SELEVER intervention in the context of the cluster randomized controlled trial.

This paper is based on an observational mixed-methods study that included a literature review, pathways analysis, and primary and secondary data analysis. A theory-based framework was developed to map the different pathways linking WASH, animal husbandry practices, and child nutrition and development outcomes. This framework was used to critically review the literature on each of the pathways involved. Hygiene-related programmatic materials from the SELEVER intervention were also reviewed. Secondary data were analyzed on livestock rearing, WASH practices, and exposure to human and livestock feces. Primary research included data collection from three selected villages where SELEVER activities were being piloted, including direct observations of 20 caregiver-child pairs, in-depth interviews, and focus groups.

The literature review suggested that WASH interventions have substantial potential for improving child nutrition, though the evidence on their effectiveness is far from definitive. The secondary data analysis confirmed that exposure to poultry and poultry feces is extremely widespread in Burkina Faso. Fully 80 percent of rural households owned poultry, and most poultry could roam freely throughout the compound. Visible animal feces were reported in 84 percent of compounds in both the CHANGE and PROMIS surveys. Moreover, WASH practices and general hygiene were very low: toilet ownership was extremely low (22 percent nationally), water supply was a major constraint, and handwashing with soap was very rare (in the CHANGE survey, only 2 percent of households reported having soap for handwashing). The primary data confirmed the poor state of WASH, extreme exposure to poultry and poultry feces, and poor knowledge of the risks associated with children's exposure to animal feces. The hygiene-related content of the SELEVER intervention focuses primarily on the promotion of practical measures to improve WASH-related practices at the household level, including food preparation, water and sanitation, and waste management, with some messaging on the risks of exposure to animal feces.

Emerging evidence suggests that exposure to animal feces is an important health risk for young children. However, the question of how to best mitigate this risk programmatically is still unclear. In rural Burkina Faso, the general WASH environment appears severely constrained, and free-scavenging poultry production systems are ubiquitous. These findings suggest the opportunity to develop a community-oriented behavioral change intervention that emphasizes, rather than isolates, the importance of reducing children's exposure to poultry feces. In the context of SELEVER, this intervention would aim to increase production and consumption of poultry products while concomitantly reducing children's exposure to poultry feces. Scaling up an intensive WASH package alongside the standard SELEVER intervention in the context of the randomized trial would provide rigorous, policy-relevant evidence in this emerging field.

Keywords: formative research, poultry value chain, nutrition, hygiene

ACKNOWLEDGMENTS

The formative research was undertaken by a team at IFPRI and AFRICSante including (alphabetically) Elodie Becquey, Rasmané Ganaba, Aulo Gelli, Derek Headey, Lieven Huybregts, Francis Ngure, Abdoulaye Pedehombga, Armande Sanou, Abdoulaye Traore, Florence Zongo, and Amanda Zongrone. Author contributions are as follows: Study design: AG, DH, FN. Literature review: FN, DH. Secondary data analysis: DH, LH, EB. Primary data collection: RG, AT, AP, LH, EB, FN, AZ, AG, AS, FZ. Primary data analysis: AG, AT, AP, AS, FZ, RG. We would like to thank the Agribusiness Systems International team—including Romain Kenfack, Sita Zougouri, Jean-Marie Zongo, Dimlawende Ouedraogo, Stephane Tuina, and Hannah Guedenet—without whom this work would not have been possible. We are very grateful to Nicole Rosenvaigue for the translations from French and to Marie Ruel for feedback on the study design.

1. BACKGROUND

IFPRI is conducting a five-year impact evaluation designed to address key gaps in knowledge about the impact of poultry value chain interventions on the diets, health, and nutritional status of women and children in Burkina Faso. The impact evaluation is designed around the scale-up of the *Soutenir l'Exploitation Familiale pour Lancer l'Élevage des Volailles et Valoriser l'Économie Rurale* (SELEVER) project, a five-year program funded by the Bill & Melinda Gates Foundation. The SELEVER project is implemented by Agribusiness Systems International (ASI) in partnership with selected local nongovernmental organizations (NGOs), private institutions, and governmental services. SELEVER is designed to leverage agriculture development strategies and nutrition to increase poultry production and improve the diets of women and children in the Centre-Ouest, Boucle de Mouhoun, and Hauts-Bassins regions of Burkina Faso.

More than 60 percent of infectious diseases in humans are caused by zoonotic pathogens (Karesh et al. 2012). One specific emerging risk associated with keeping livestock is the elevation of disease burdens related to the close proximity of animals and humans, such as increased exposure to zoonotic diseases, including elevated risks of diarrhea (Zambrano et al. 2014) and environmental enteric dysfunction (Ngure et al. 2013), as well as respiratory infections (ATS 1998). Poultry are a particular concern given that scavenging poultry systems involve poultry roaming in and around the main household dwelling, thereby exposing young children (who are often left alone to sit or play on the ground) to the ingestion of chicken fecal matter. Formative research in Zimbabwe observed young children for prolonged periods (six-hour stretches) and found that some children directly ingested or mouthed poultry feces or soils contaminated with poultry feces. Poultry were also observed to roam freely in homestead gardens where children sit and explore, as well as in the homestead. Ingestion of chicken feces by young children has also been reported in a peri-urban setting in Peru (Marquis et al. 1990). The study in Zimbabwe found that poultry feces had extremely high concentrations of *E. coli* bacteria, and ingestion of such bacteria is an important contributor to fecal bacterial overload of the small intestine, which may result in chronic inflammation of the gut and low-level immune system stimulation, a condition now termed environmental enteric dysfunction, or EED. Research from Ethiopia and Bangladesh documents that many households keep poultry within the home itself overnight, often in the same room where children sleep (Headey and Hirvonen 2016; George, Oldja, Biswas, Perin, Lee, Ahmed, et al. 2015). Both studies found this practice to be associated with child stunting, and the Bangladesh study found that keeping poultry in the main household dwelling also increased the risk of EED symptoms. Another recent unpublished study reported that animal feces were observed in the homestead compound in 40 percent of households in Bangladesh, Ethiopia, and Vietnam (Headey et al. 2016). In many countries, we also know that young children are left to sit unattended on the floors of homesteads or gardens, or are attended to only by other young children.

Poultry is the most commonly owned livestock in Burkina Faso, with 80 percent of households reporting ownership of at least one bird. Poultry play a critical role in income generation and diet diversification in a very poor socioeconomic setting, implying that there may well be substantial potential for increased productivity and commercialization to further improve incomes and diets, and hence health and nutrition. Emerging evidence from multiple low- and middle-income countries, however, raises concerns about other adverse pathways of impact on nutrition and health, particularly via children's exposure to fecal matter from poultry. Still other research emphasizes the risk that exposure to poultry can increase the incidence of respiratory infections. Despite having the largest ownership rates of poultry among all Demographic Health Survey (DHS) countries, and very poor water, sanitation, and hygiene (WASH) conditions, Burkina Faso has not, to our knowledge, been the subject of any previous study or intervention to assess these risks or promote specific, intensive interventions to address them.

This formative research study was aimed at assessing the need for a potential intensive WASH and poultry-related hygiene intervention that could be rolled out alongside the SELEVER package in the context of the cluster randomized controlled trial (RCT) in Burkina Faso. The formative research focused on four key questions:

1. To what extent are rural Burkinabe children exposed to poultry feces and other animal feces?
2. What are the general hygiene levels of rural people in SELEVER pilot villages?
3. What type of hygiene messaging is SELEVER engaging in during its pilot phase (in 2016)?
4. What is the scope for projects to incorporate a more intensive livestock-hygiene component?

In this paper we present the findings of the formative research. The rest of the paper is structured as follows: In section 2 we describe the methods for the different elements involved in the analysis. Section 3 outlines a theory-based framework describing the connections between food systems, WASH, animal husbandry, and the various common infections that may contribute to undernutrition in early childhood, and then summarizes the evidence on the different pathways involved, with a particular focus on livestock and WASH. Section 4 uses a range of secondary data sources to assess rates of poultry ownership in Burkina Faso, children's exposure to animal feces, and more generic WASH conditions. Section 5 summarizes the main findings of the primary research, including household observations, in-depth interviews, and focus groups. In section 6 we discuss the main findings and then conclude.

2. METHODS

We designed an observational study combining quantitative and qualitative methods, involving a literature review, pathways analysis, and the analysis of primary and secondary data.

Literature Review and Program Theory for Interventions

In light of the fact that the evidence base on both WASH-nutrition and livestock-nutrition linkages is expanding rapidly, we set out to critically review this evidence, particularly recent evidence. The review component had three objectives. The first was to outline a framework for mapping the different pathways linking WASH, animal husbandry practices, and nutrition and childhood development outcomes. The second was to extensively review and update the evidence on both WASH-nutrition and livestock-nutrition linkages. The third and final objective was to provide some critical reflections on the implications of this evidence base for designing potential interventions to mitigate the risks that poor WASH conditions and animal husbandry practices pose for child nutrition and development. The review involved searching for literature on each of the linkages described in the framework. We engaged in a critical review rather than a systematic review, emphasizing the most important findings and commenting on the strengths and weaknesses of different studies. In addition, we also reviewed the programmatic materials developed by SELEVER, with a focus on identifying the sanitation- and hygiene-related content and messages that will be promoted.

Secondary Data Analysis

We assessed data related to livestock rearing and WASH behaviors that were collected as part of the CHANGE and PROMIS studies, including data on WASH practices, animal ownership, and livestock-related hygiene behaviors. The CHANGE study evaluated the impact of a multicomponent intervention program on child health, nutrition, and development implemented by Helen Keller International (HKI). The study area comprised 60 villages located in four communes (Diapangou, Diabo, Tibga, and Yamba) of the Gourma province in eastern Burkina Faso (see Olney et al. [2015] for more information on the CHANGE study). These villages were selected using three criteria: a sufficient population size, availability of water for small-scale agricultural activities during the dry season, and the absence of other nutrition- or food security–related interventions implemented by HKI. All households that had a child between the ages of 0 and 11.9 months of age at the time of the baseline survey (April–May 2014) were invited to participate in the survey, which led to a total baseline sample size of 2,494 households.

The PROMIS study evaluated the impact of a comprehensive preventive intervention package on child acute malnutrition prevalence and incidence (see Huybregts et al. [2017] for more information on the PROMIS study). The study area included 1 urban and 32 rural health center catchment areas situated in one commune (Gourcy) of the Nord region in northern Burkina Faso. All the villages in a health center catchment area were included in the study, with the exception of health center catchment areas with more than three villages, in which case three villages were randomly selected using a "probability proportional to population size" approach. Prior to the baseline study, a census was undertaken in all selected villages. An equal number of eligible households per village were then randomly selected from the census lists. The baseline study was conducted in October–November 2014 and included 2,368 households with at least one child 0–17 months of age.

Both baseline surveys assessed the WASH conditions of the household, including observing the presence of animals and fecal matter in the compound and the presence of latrines and handwashing facilities. Specific emphasis was placed on assessing the extent to which a child was exposed to small animals and livestock in the compound. Furthermore, household garbage disposal strategies were assessed through a questionnaire. Water quality was assessed by asking questions on primary and secondary water sources and water treatment and storage strategies. Finally, the questionnaire assessed child caregivers' hygiene knowledge.

Primary Research

The primary research, following Ngure et al. (2013), included quantitative and qualitative data to identify (1) major pathways of fecal-oral microbial transmission among young children and (2) feasible intervention options in the SELEVER study population in Burkina Faso. The study area included three villages purposely selected from the pool of villages where SELEVER activities are being piloted. A total of 20 households with children in three age groups (6–12 months, 12–24 months, and 24–36 months, with seven caregiver-child pairs in each age group) were purposely selected for the direct observations and semistructured interviews. Ten of the 20 households had flocks of more than 20 chickens and/or other fowl.

Data collection included direct observations of caregivers and infants and livestock/WASH-related behaviors in 20 households. The observations were conducted during a four-hour period in each household, recording with a time stamp every object touched or mouthed by an infant, whether the object was visibly dirty, and the frequency of object-to-mouth episodes. Mothers' handwashing practices and toileting-related behaviors were also recorded. A second set of observations was undertaken in parallel in the same households, using a semistructured questionnaire to determine the WASH environment in the household (existence and evidence of use of a handwashing station and functioning latrine). Spot checks were undertaken at hourly intervals during the observation period to record the number of roaming animals, the presence of fecal material in the child's surroundings, and the cleanliness of the mother's and child's hands. Once the observation was completed, in-depth interviews were conducted with the mothers/caregivers regarding childcare and water, hygiene, and sanitation practices, including disposal of animal feces, to identify possible strategies to tackle WASH-related childcare constraints. In addition, four focus group discussions were conducted in the three villages, including groups of mothers and groups of fathers from poultry-producing households with children aged 6 to 36 months. Each group included at least eight participants, half of whom owned flocks of more than 20 chickens and/or other fowl. The focus group discussions were guided by trained facilitators, exploring issues related to the risks associated with fecal oral microbial transmission in young children, WASH knowledge and practices in the community, and the scope and feasibility of possible interventions. Trained enumerators recorded all focus group discussions and interviews using digital handheld audio devices.

Debriefings were held with the interviewers once the data collection was completed to identify key themes and provide a preliminary code list for the analysis. Audio recordings were transcribed from local languages and translated into French and English. Transcriptions were de-identified and submitted to the research team for coding and analysis. The preliminary code list was further developed prior to analysis by thematic code list groupings. Relevant codes were added as needed as they emerged from the data. The training of enumerators was undertaken between October 17 and 21 and included visits to two SELEVER-assisted communities. Data collection was completed over the following two weeks.

3. PROGRAM THEORY AND LITERATURE REVIEW

In this section we first outline a theory-based framework describing the connections between food systems, WASH, animal husbandry, and the various common infections that may contribute to undernutrition in early childhood, and then summarize the evidence on the different pathways involved, with a particular focus on livestock and WASH.

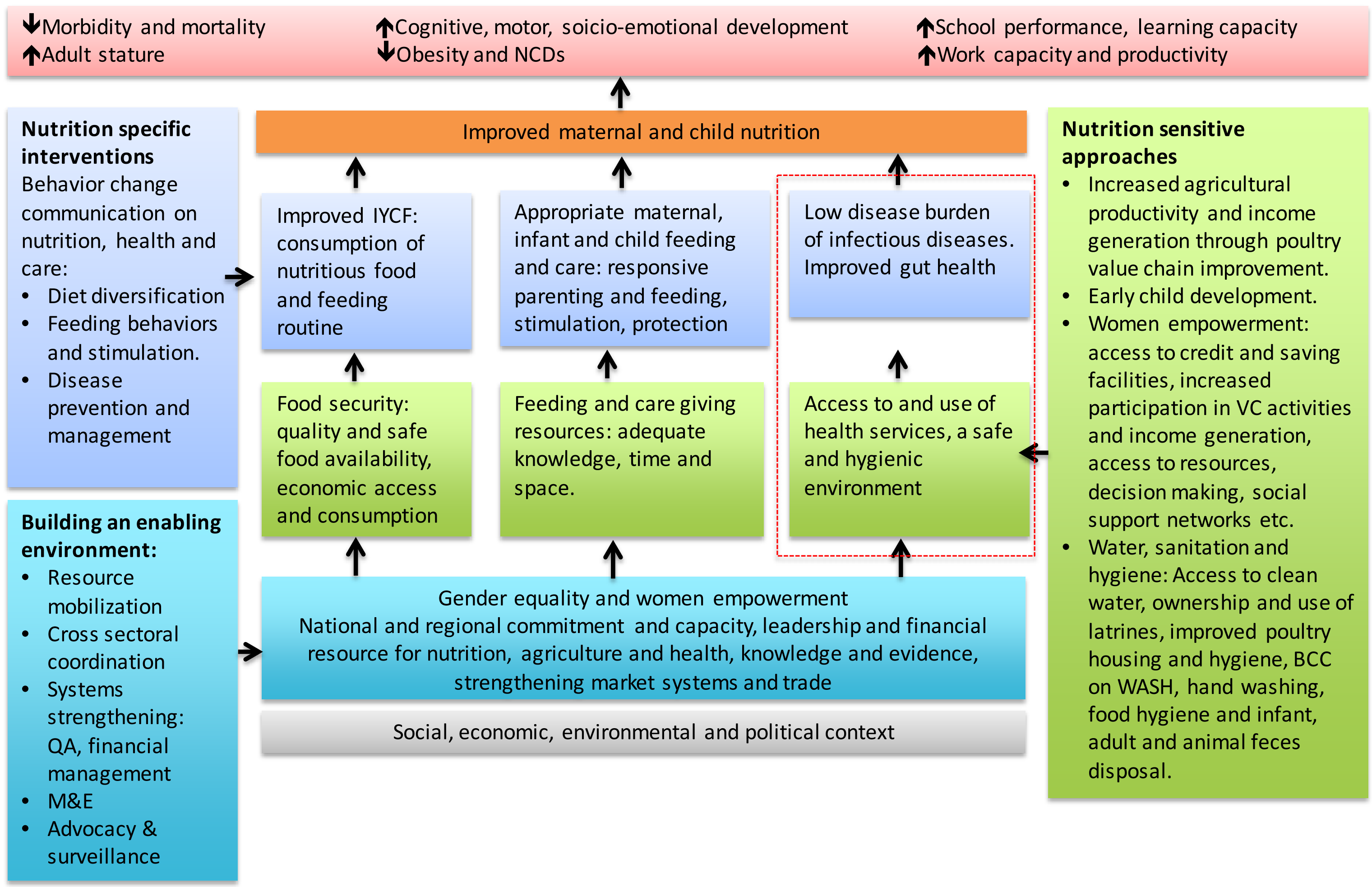
Pathways Linking Interventions in Food Systems, WASH, Health, and Nutrition

Food systems include all the activities, resources, and infrastructure involved in food production, processing, transport, marketing, consumption, and disposal of food that originates from agriculture, livestock, pastoralism, fisheries (including aquaculture), and forestry (CFS 2014). They involve a broad range of stakeholders (food producers, food chain actors, and consumers, for example) operating at different levels (global to local) and linked in different, context-specific configurations.

The links between food systems, diets, nutrition, and health are manifold and complex, involving a range of direct and indirect effects and lags that are not yet well understood (Herforth and Ahmed 2015; Pinstrup-Andersen 2012; Popkin and Hawkes 2016). To better understand the program theory for interventions in food systems, we build on the 2013 Lancet Series framework on Maternal and Child Nutrition (Black et al. 2013). In this framework, optimal nutrition is determined by dietary, behavioral, and health determinants, influenced by underlying food security, caregiving resource, and environmental conditions (Figure 3.1).

Nutrition-specific interventions address the immediate determinants of undernutrition, such as inadequate food and nutrient intake, suboptimal care and feeding practices, and poor health (Ruel and Alderman 2013). Nutrition-sensitive programs involve interventions that address the underlying causes of undernutrition—including poverty; food insecurity; poor maternal health, education, social status, and/or empowerment; and limited access to water, sanitation, hygiene, and health services—and also incorporate specific nutrition goals and actions. Nutrition-sensitive programs are often implemented at scale and can be leveraged as delivery platforms for nutrition-specific interventions, thus providing opportunities to accelerate progress in tackling malnutrition. Nutrition-sensitive programs can affect nutrition through changes in prices (both food and nonfood) and through income and women's empowerment (Ruel and Alderman 2013). Agricultural interventions can affect nutrition outcomes through a range of complex pathways (Masset et al. 2011; Headey et al. 2012; Webb 2013). These pathways linking agricultural inputs, allocation of intrahousehold resources, and child nutrition are mediated by women's empowerment, including social status, control over resources, time allocation, and health and nutrition status (van den Bold et al. 2014). From a food intake perspective, agricultural production is just one factor involved in shaping diets (FAO 2011). The storage, distribution, processing, marketing, preparation, and consumption of foods can influence their availability, access, acceptability, quality, and safety. Improvements in diet quality may also be necessary but not sufficient to result in improved nutrition, if the limiting constraints in the other determinants of nutrition are not also simultaneously addressed.

Figure 3.1 Achieving optimal child nutrition and development through food systems interventions



Source: Adapted from Black et al. (2013).

Note: The dashed box highlights the main pathways through which additional risks from WASH and poultry-related production practices could influence child nutrition. BCC = behavior change communication; IYCF = infant and young child feeding; M&E = monitoring and evaluation; NCDs = noncommunicable diseases; QA = quality assurance; VC = Value chain; WASH = water, sanitation, and hygiene.

Livestock interventions are often designed with income objectives alone, but they increasingly have strong nutritional rationales because of the high-quality protein and nutrient density of many animal sourced foods (FAO 2013; Iannotti, Muehlhoff, and McMahon 2013; Iannotti et al. 2014; Murphy and Allen 2003; Neumann, Harris, and Rogers 2002). However, from a nutrition and health perspective, the impact of livestock interventions on the disease environment is a growing concern because greater ownership of livestock could lead to more contamination of the homestead compound or water supply with animal feces (Ngure et al. 2013; Ngure et al. 2014; Schriewer et al. 2015), as well as increased risk of respiratory illness (ATS 1998) and perhaps even malaria (Donnelly et al. 2015). Hence, ownership of livestock could influence exposure to a wide range of infections that might ultimately be harmful to nutrition.

WASH interventions have long been thought to be of major importance in improving nutrition, through their impact on reducing exposure to infections, particularly diarrhea and other water-borne diseases, EED, soil-transmitted helminths (STHs), and malaria. Evidence-based WASH interventions have focused mainly on improving access to and use of toilets, improved water sources, and improved handwashing facilities and methods. Relatively few traditional WASH programs place a strong emphasis on livestock management and animal feces disposal, in part because scientists have hypothesized that human feces are more important reservoirs for the pathogenic bacteria that most commonly cause diarrhea (Curtis, Cairncross, and Yonli 2000). However, some have hypothesized that even nonpathogenic bacteria may contribute to the etiology of EED, meaning that the more-widespread livestock feces may be an important risk factor for EED. Hence, in principle, more livestock-oriented WASH programs could potentially provide an important barrier to prevent the transmission of pathogenic and nonpathogenic microbes from livestock to humans.

The following sections provide an overview of the evidence base along these hypothesized pathways.

Evidence on WASH and Nutrition Outcomes

WASH, Diarrhea, and Nutrition

Fecal contamination of the household environment is an important source of diarrheal pathogens such as *Camplyobacter jejuni*, enteropathogenic strains of *E. coli*, *Salmonella* species (Curtis, Cairncross, and Yonli 2000; Marquis et al., 1990), protozoa, viruses, and other infectious disease causative agents (Curtis, Cairncross, and Yonli 2000; Pickering et al. 2012), and appropriate WASH practices can clearly reduce this exposure. There is also strong evidence that poor WASH conditions contribute significantly to the burden of diarrheal morbidity and mortality (Esrey 1996; Checkley et al. 2004; Fink, Gunther, and Kenneth 2011; Mara et al. 2010; DFID 2013; Curtis and Cairncross 2003; Fewtrell et al. 2005; Aeillo et al. 2008; Ejemot et al. 2008; Cairncross et al. 2010), including a number of meta-analyses populated with large numbers of studies and sufficient high-quality evidence. These studies vary somewhat in terms of strength of association between WASH indicators and diarrhea, as well as in how the relevant indicators are measured. Some studies also find synergies between different WASH components, such as between time to fetch water and access to sanitation (Pickering and Davis 2012).

However, the evidence linking diarrhea to linear growth is less clear, with several studies claiming that nutritional status (height) is a more sensitive indicator of the health benefits of improved water and sanitation than diarrhea (Esrey 1996). In a longitudinal study in Peru (Checkley et al. 2004), the height difference between children experiencing the best and worst water and sanitation conditions explained 40 percent of the 2.5-centimeter deficit in height at 24 months, which was 2.5 times the effect size explained by the history of diarrheal prevalence since birth. However, one study estimated that each diarrheal episode experienced by a child in the months preceding his or her second birthday increases the risk of being stunted by 4 percent (Bhutta et al. 2008). In a pooled analysis of nine community-based studies in low-income countries, 25 percent of all stunting in 24-month-old children was attributed to having had five episodes or more of diarrhea in the first two years of life (Checkley et al. 2008). In an analysis of seven longitudinal cohort studies of children under two years of age in four low-income countries, the average child’s diarrhea burden was associated with a 0.38-centimeter height deficit at two years of age (Richard et al. 2013), an equivalent of 0.13 length-for-age Z-score or 7 percent of the average height deficit of two-year-old Asian and African children. One biological explanation for the small effect of diarrhea on long-term stunting is that growth velocity between diarrhea episodes is faster than average for age, resulting in catch-up growth. Still another explanation is that EED is the primary pathway linking poor WASH to stunting, and not diarrhea (Humphrey 2009). At the very least, the inconclusiveness of this evidence suggests that it is imperative that impact evaluations of WASH interventions assess the long-term effects on child height in addition to diarrheal morbidity.

WASH, EED, and Nutrition

Although EED and symptoms likely related to EED have been recognized as contributing to growth retardation for some time (Humphrey 2009; Korpe and Petri 2012; Ngure et al. 2014; Prendergast and Kelly 2012), research over the past decade or so has increasingly brought EED to the fore as one of the most important determinants of growth faltering in young children. Though the causal mechanism of EED in humans is not well understood, fecal bacteria overload of the small intestine is thought to be the primary cause (Humphrey 2009). Exposure to enteric bacteria and pathogens from the environment occurs early in life and is cumulative over the critical window (the first thousand days) of growth and development. Most common WASH interventions are not designed to specifically protect children from ingestion of fecal bacteria and pathogens from soil and animal feces (Ngure et al. 2013) at this critical window.

Research in Gambia has documented the relative contribution of EED to poor growth. Among Gambian infants, growth faltering was associated with intestinal permeability but not with dietary inadequacy or clinical diarrhea (Lunn et al. 1991). Intestinal permeability accounted for 39 percent of weight and 43 percent of linear growth failure in Gambian infants and young children. Further research in Gambia has provided evidence of links between chronic inflammation of the small intestine mucosal lining, systemic immune activation, and subsequent growth impairment (Campbell 2003). Elevated markers of immune stimulation and abnormal intestinal permeability (indicative of EED) were negatively associated with child growth (Campbell 2003). The interrelationships between the markers of immune stimulation, EED, and growth suggest that they are part of the same mechanism that could explain up to 55 percent of growth retardation. Other studies have also shown an association of gut inflammation and intestinal permeability with poor growth in other low-income contexts (Campbell et al. 2004; Kosek et al. 2013; Lin et al. 2013; Weisz et al. 2012; Goto et al. 2009; Panter-Brick et al. 2008; George et al. 2016; Guerrant et al. 2016).

Although the causes of EED are not yet extensively documented, poor personal hygiene and substandard hygienic conditions in the external environment are associated with EED and poor linear growth. In an observational follow-up study of 10- to 48-month-old children in Bangladesh, young children living in cleaner household environments had lower levels of parasitic infection, improved measures of gut function, and improved growth compared to their peers living in contaminated environments (Lin et al. 2013). This suggests that more comprehensive interventions that involve improving environmental sanitation and holistic hygiene behavior, rather than targeting individual WASH aspects alone, will be critical in preventing chronic undernutrition in areas with high fecal contamination.

WASH, Acute Respiratory Infections, and Undernutrition

Co-occurrence of respiratory and gastrointestinal infections has been reported in Bangladesh (Leung et al. 2015), Pakistan (Ashraf et al. 2013), and India and Nepal (Walker et al. 2013). Diarrhea was associated with increased risk of acute lower respiratory infections (ALRIs) in Indian and Nepali children (Walker et al. 2013) and in undernourished child populations in Ghana (Schmidt et al. 2009). The risk of comorbidities increased with the severity of the diarrhea (Walker et al. 2013). Recent diarrhea was also associated with increased risk of pneumonia in Pakistani children under five years old (Ashraf et al. 2013). Breastfeeding was protective against concomitant pneumonia in under-12-month-old Bangladeshi infants, whereas severe acute malnutrition increased the risk (Leung et al. 2015). There is a need for large-scale and long-term longitudinal studies to confirm the associations between diarrhea, undernutrition, and subsequent risk of ALRIs. However, the current evidence suggests that ALRIs are largely an endpoint of a long chain of causal factors including poverty, nutrition, and environmental health (water, sanitation, and indoor air pollution). Nevertheless, diarrhea may be an important mediating pathway linking poor conditions of WASH to ALRIs. However, there is limited evidence on the impact of respiratory infections on linear growth. The most common mild upper respiratory infections are unlikely to have persistent effects in most children, though respiratory infections with fever are associated with higher risk of stunting (Adair and Guilkey 1997), perhaps because fever is an indicator of systemic immune stimulation, which suppresses appetite and diverts energy and nutrients away from growth processes.

WASH, STHs, and Nutrition

STHs are associated with child undernutrition (Prüss-Üstün and Corvalán 2006) and anemia (Stoltzfus et al. 2004). Because repeated antihelminthic treatment is only an effective short-term strategy in addressing the burden of STHs in contexts with poor WASH conditions, improving WASH remains an essential component of long-term strategies to eliminate STH infections. A recent meta-analysis of the impacts of antihelminthic mass treatment on child nutrition outcomes found little effect (Welch et al. 2017). Access to and use of sanitation facilities is associated with significant protection against STHs, with one study suggesting that combined STH infections can fall by half (Ziegelbauer et al. 2012). In a systematic review and meta-analysis of 94 studies, the majority being cross-sectional studies, use of improved individual WASH practices and access to sanitation facilities were associated with one-third lower odds of STH infections (Strunz et al. 2014).

WASH and Anemia

Childhood anemia is a significant public health problem, and, like stunting, it is prevalent in Asia and Africa (Black et al. 2013). About half of pediatric anemia has not been resolved through dietary interventions (Stoltzfus, Mullany, and Black 2002), suggesting that various recurrent childhood infections account for the bulk of the residual causes of anemia (Weiss 2005). Low levels of chronic inflammation and immune stimulation as a result of EED may be an important cause of anemia (Humphrey et al. 2015;

Ngure et al. 2014; Prendergast et al. 2015), primarily through elevated production of hepcidin by the liver, which suppresses iron absorption and utilization (Nemeth et al. 2004; Prentice et al. 2012), and suppression of erythropoiesis, leading to anemia of inflammation (Jelkmann, Wolff, and Fandrey 1989). Intestinal helminths transmitted through soil that is contaminated with animal and human feces cause poor appetite and also worsen undernutrition and anemia (Stephenson et al. 2000; Stoltzfus et al. 2004). Hookworm infection causes intestinal blood loss and increased risk of severe anemia (Stoltzfus et al. 1996).

Despite these various biological mechanisms linking WASH to anemia, there is surprisingly little evidence on the impacts of WASH practices or WASH interventions on anemia. In a cross-country correlation analysis using 81 DHS datasets covering 45 countries in Africa south of the Sahara, Latin America, Europe, and Asia, poor sanitation is strongly associated with low hemoglobin, independent of income, measures of food intake, and malaria incidence (Coffey, Geruso, and Spears 2016). More in-depth analyses of 2006 and 2011 DHS datasets for Nepal reveal a robust relationship between open defecation and higher hemoglobin levels. After controlling for a household's own defecation practices, household socioeconomic characteristics, and regional fixed effects, a 10 percentage point decrease in the proportion of neighbors who openly defecate was associated with a 0.13 g/dL increase in hemoglobin levels, or about 9 percent of a standard deviation (Coffey, Geruso, and Spears 2016). This effect size is approximately one-third to two-thirds of the effect sizes (0.20 g/dL–0.41 g/dL) observed from experimental evidence on micronutrient supplementation (Friis et al. 2003), iron supplementation (Lind et al. 2003) and iron fortification in foods (van Stuijvenberg et al. 1999), and parasite treatment (Friis et al. 2003). These associations are therefore large in absolute magnitude—though, surprisingly, Nepal did not experience any significant reduction in child anemia across the 2005 and 2011 DHS rounds. Thus, further evidence is needed to corroborate a causal impact, including RCT evidence. The results suggest, however, that supplementation, fortification, and dietary diversification approaches are unlikely to adequately address anemia if the adverse public effects of open defecation are not addressed.

Observational Evidence on WASH and Nutrition Outcomes

Several large-scale observational studies, including multicountry studies, have demonstrated an association between improved water and sanitation and linear growth (Esrey 1996; Checkley et al. 2004; Merchant et al. 2003; Fink, Gunther, and Kenneth 2011; Spears 2012). Recent analyses of the potential drivers of change in height-for-age Z-scores (HAZ) and stunting over time in Bangladesh (Headey et al. 2015), Nepal (Headey and Hoddinott 2015), and other South Asian countries (Headey, Hoddinott, and Park 2016) all find that improvements in sanitation statistically explain improvements in HAZ and/or stunting over time (i.e., multiple rounds of the DHS). Another recent study also finds associations between sanitation and child anemia in Nepal (Coffey, Geruso, and Spears 2016). Some studies find no synergistic effects between sanitation and water (Rah et al. 2015; Merchant et al. 2003), but others do (Esrey 1996; Checkley et al. 2004). Econometric analyses of sanitation-nutrition relationships have also explored nonlinear effects and public health externalities or spillovers. These analyses find some evidence that latrine quality matters (Fink, Günther, and Hill 2011), that sanitation's associations with linear growth are stronger for community-based open defecation measures than for household measures (Spears 2013), that open defecation has much more adverse associations in densely populated communities and more urbanized areas (Hathi et al. 2014; Spears 2013; Spears, Ghosh, and Cumming 2013), and that sanitation-HAZ relationships become much stronger when community open defecation rates fall below 30 percent (Headey et al. 2015).

Experimental Evidence on WASH Interventions and Nutrition

A meta-analysis of five cluster RCTs showed a modest effect of water and hygiene interventions on HAZ (mean difference 0.08; 95 percent CI 0.00 to 0.16) in children under five years old (Dangour et al. 2013). The interventions included solar disinfection of water, provision of soap, and improvement of water quality. The small benefit to growth was attributed to relatively short-term interventions (9–12 months) of relatively low methodological quality (Dangour et al. 2013). High-quality sanitation interventions are arguably more likely to have larger impacts on linear growth because toilet use is the primary barrier to fecal contamination of infant and child feeding and play environments. However, many sanitation cluster

RCTs have not shown significant changes in linear growth outcomes across treatment and control groups. While these limited impacts are discouraging, these studies have themselves acknowledged important shortcomings, as have several reviews and commentaries (Headey 2016). First, these interventions in India and Indonesia were unable to achieve substantial increases in the use of toilets, perhaps because of relatively weak behavior change communication components. Moreover, in Indian sites where toilet access nominally increased quite rapidly, qualitative research found that many government-constructed toilets were incomplete and not widely used (Routray et al. 2015). Second, as in other WASH interventions, the time frame of these evaluations was relatively short. In several instances authors reported an average duration of exposure to treatment of just six months.

In contrast, a more recent study in Koulikoro district of Mali found substantially larger impacts. Unlike the studies cited above, this intervention involved intensive behavior change communication measures over a 12-month period, which resulted in much wider adoption of toilets. Children exposed to community-led total sanitation (CLTS) were significantly taller (0.18 increase in HAZ; 95 percent CI 0.03–0.32) and less likely to be stunted (6 percentage points reduction in prevalence) at endline compared to those from the control arm (Pickering et al. 2015). These effects in height were driven by gains in younger children, under two years at enrollment (0.24 HAZ). These findings further highlight the importance of the first two years of life as the critical window for addressing stunting. Using experimentally induced estimates on village-level open defecation from pooled data from four of the RCTs discussed above—Mali (Pickering et al. 2015), Indonesia (Cameron et al. 2013), Tanzania (Briceño, Aidan, and Martinez 2014), and India (Patil et al. 2015)—Gertler et al. (2014) estimate that moving from universal to zero open defecation rates would improve child HAZ by 0.44 standard deviations, a far more moderate effect compared to that suggested by a cross-country econometrics study, which reports an increase of at least 1 standard deviation in HAZ with eradication of open defecation (Spears 2013). The result is consistent with the modest to small reductions in open defecation reported in previous RCTs having a limited impact on HAZ.

Livestock as a Risk Factor for Common Childhood Infections and Stunting

Livestock as a Risk Factor for Diarrhea

Traditionally, WASH interventions have focused primarily on reducing exposure to human feces, though it is also well known that animals are potentially important reservoirs of some pathogenic bacteria. However, there are several reasons why the WASH community may be underestimating the risks that livestock pose for diarrheal disease in young children. First, animal feces exposure may be more widespread than exposure to human feces in many low-income settings. In a microbiological analysis of villages in rural India, for example, animal feces contamination of household stored water, both mothers' and children's hands, and public water sources was significantly more widespread than human feces contamination (Schriewer et al. 2015), even in a setting where open defecation is still reasonably common. In many other parts of the developing world, open defecation is now substantially rarer than it was several decades ago, meaning exposure to animal feces is much more common than exposure to human feces. Indeed, evidence from hygiene spot checks carried out as part of household surveys conducted in Ethiopia, Bangladesh, and Vietnam indicates than animal feces were much more regularly observed (approximately 40 percent of households in all three countries) than human feces (less than 5 percent in Bangladesh and Vietnam, and 16 percent in Ethiopia).

Second, livestock ownership is extremely widespread in rural and peri-urban settings in developing countries. Using data from the DHS, Headey and Hirvonen (2015) show that the majority of rural households in Africa and South Asia own some form of livestock, with poultry being the most common type. The widespread ownership of poultry may be of particular concern from a diarrheal perspective because several studies have isolated pathogenic bacteria (Simango 2006; Marquis 1990) and other fecal bacteria from soil and chicken feces sampled from the domestic environment (Pickering et al. 2012; Ngure et al. 2013). Moreover, infants and young children frequently explore, crawl, and feed in such contaminated environments. Direct exploratory ingestion of contaminated soil and chicken feces has been observed in various contexts, such as Peru (Marquis et al. 1990), Zimbabwe (Ngure et al. 2013), Ethiopia (Save the Children/Ethiopia and Manoff Group 2014), and Bangladesh (George, Oldja, Biswas, Perin, Lee, Ahmed, et al. 2015). Handwashing with soap is rare among infants and young children, and inadequate among caregivers in similar contexts (Ngure et al. 2013).

Third, there is some evidence that livestock ownership is indeed associated with diarrhea incidence. In a systematic review of 29 studies on risk factors for diarrhea, 69 percent of the studies showed an association between exposure to domestic food-producing animals and diarrheal illness (Zambrano et al. 2014). Exposure to domestic poultry more than doubled the risk of human campylobacteriosis (OR 2.73, 95 percent CI 1.90–3.93), corroborating evidence from earlier studies linking poultry to campylobacteriosis (Akitoye et al. 2002). However, failure to identify the microbial cause of disease might have led to an underestimation of this effect because a significant number of molecular studies provide compelling evidence that identical protozoal strains exist in both domestic animals and humans (Zambrano et al. 2014). Measurement issues may also explain why some more recent observational studies find only weak associations between maternal reports of recent diarrhea incidence and livestock ownership (Kaur, Graham, and Eisenberg 2017) or the presence of animal feces in the household compound (Headey et al. 2016).

Livestock as a Risk Factor for EED and Undernutrition

In addition to diarrhea, ingestion of animal feces could contribute to child undernutrition via EED. Mbuya and Humphrey (2016) hypothesize that even nonpathogenic bacteria may contribute to EED. If so, it is possible that animal feces are a larger risk for EED than human feces because of the greater exposure of young children to animal feces. The direct evidence of this stems from a small observational study of poultry-owning households in Bangladesh. This study found that having an animal corral within a child's sleeping room was associated with elevated EED scores and doubled odds of child stunting (George, Oldja, Biswas, Perin, Lee, Ahmed, et al. 2015). The most common animals corralled in the children's sleeping room were chickens and cows, which are important sources of the common zoonotic diseases campylobacter and diarrheic E. coli (Bender 2004). A study by the same research group also found that a maternal report of geophagy, which likely leads to ingestion of animal fecal matter, was also significantly associated with EED and stunting (George, Oldja, Biswas, Perin, Lee, Kosek, et al. 2015).

These findings were corroborated by a much larger observational study of an agricultural survey in rural Ethiopia (Headey and Hirvonen 2016). Unlike the studies by George and colleagues (George, Oldja, Biswas, Perin, Lee, Kosek, et al. 2015; George, Oldja, Biswas, Perin, Lee, Ahmed, et al. 2015), Headey and Hirvonen (2016) used a much broader sample of rural households owning different types of livestock. They found that although poultry ownership was positively associated with linear growth in young children, corralling poultry indoors had a negative association with linear growth. In contrast, they found no adverse effects of corralling other livestock species indoors.

A recent three-country observational study by Headey et al. (2016) tested for associations between hygiene spot-check measures made by survey enumerators and child growth outcomes in Ethiopia, Bangladesh, and Vietnam. In both Ethiopia and Bangladesh, they found negative associations between animal feces in the compound and child HAZ, but no significant association in Vietnam. These results are compelling because the authors were able to control for various other dimensions of household hygiene, such as the cleanliness of mothers and children, the cleanliness of the compound in general, and the types of toilet and water facilities used. The authors note that the lack of an association in Vietnam may be explained by the much better hygiene standards there and the much lower prevalence of stunting.

Two studies using a prospective cohort survey in western Kenya found strong links between livestock disease and human morbidity and nutrition outcomes. Mosites et al. (2016) found that livestock digestive disorders were associated with reduced height gain in children under five and with reduced weight gain in children under two (Mosites et al. 2016). A previous study within the same cohort demonstrated that livestock disease reports were associated with human disease reports (Thumbi et al. 2015).

All these studies are observational in nature, meaning that the associations between livestock indicators and child nutrition or EED markers cannot be interpreted as causal. Moreover, the biological mechanisms for these potential pathways remain unclear. Close proximity to livestock may mean higher exposure to zoonotic pathogens that cause infectious diarrhea and/or EED, and subsequent growth failure (Checkley et al. 2008; Schlaudecker, Steinhoff, and Moore 2011). Animal corralling practices and frequent livestock diseases may also be reflective of poor household hygiene standards or lower socioeconomic status, which may be only imperfectly controlled for.

Livestock as a Risk Factor for Acute Respiratory Infections

Exposure to domestic animals is an important risk for common childhood illnesses. Close proximity to poultry has been associated with increased risk of acute respiratory infection in children and adults, including a number of studies on poultry workers in more developed countries (ATS 1998). In 2003 the first H5N1 avian flu strains were observed in China and subsequently in many other countries, including Bangladesh, Vietnam, Indonesia, Thailand, Egypt, and Nigeria. Several studies find that exposure to sick birds in live bird markets is associated with avian flu infections, and these risks are compounded by poor hygiene (Liu et al. 2014; Nasreen et al. 2015). Moreover, there is growing evidence that the incidence of avian flu infection may be significantly underestimated (Gomaa et al. 2015; Khuntirat et al. 2011), partly because many infections may be subclinical. Notably, we found no studies linking respiratory infections in young children to exposure to poultry or other livestock, suggesting that this may be a neglected area of research.

Livestock as a Risk Factor for Malaria

Livestock have ambiguous impacts on malaria transmission. Livestock can draw mosquitoes away from humans, decreasing human-vector contact and malaria transmission (zooprophylaxis), but livestock can also draw mosquitoes to humans, increasing malaria transmission (zoopotentiation). Proactive zooprophylaxis approaches have been advocated for reducing the risk of malaria transmission (Mutero et al. 2004). A critical review of 20 empirical studies covering both experimental and observational study designs assessed impacts on human malaria infection and mosquito feeding behavior (Donnelly et al. 2015). Factors determining whether livestock facilitated or hindered malaria transmission were the characteristics of the local mosquito vector, the location of livestock relative to human sleeping quarters, the use of bed nets, and socioeconomic status. Zoopotentiation is most likely to occur where livestock are housed within or near human sleeping quarters at night and where mosquito species prefer human hosts. Notably, however, the majority of studies on livestock practices and malaria focus on cattle. One recent paper suggestions that poultry may actually repel malarial mosquitoes (Jaleta et al. 2016). There is, however, limited evidence on the impact of malaria on nutrition, partly because the relationship is bidirectional. There is some evidence that malaria during pregnancy leads to worse birth outcomes (Eisele et al. 2012; Guyatt and Snow 2004; Unger et al. 2016).

Review of Hygiene Messaging in SELEVER

The SELEVER training package includes a specific module on hygiene as it relates to food, general living conditions, and the disposal of poultry feces. The training module on hygiene will be rolled out alongside the other gender and nutrition modules in SELEVER through a cascade model, involving the training of trainers, including ASI's NGO partners, who will then train the SELEVER beneficiary associations, volunteer vaccinators, community leaders, and poultry producer groups. The hygiene training is expected to last three days and has the following goals for participants:

- Mastering the main principles of food hygiene and hygiene in everyday life
- Applying a minimum set of hygiene rules in the household environment
- Adequately managing poultry feces

The training module is organized around three main topics (or sessions): (1) a general introduction to hygiene, (2) food- and water-related hygiene, and (3) hygiene and the environment. The content in each session is divided into lessons that cover relevant subtopics. Each lesson includes educational objectives, tools, instructions for the facilitators, general content, a summary of the lesson, and key messages.

General Introduction to Hygiene

The training module begins with a session on the importance of hygiene in general. Hygiene is defined as the "set of measures intended to prevent infections and the emergence of infectious diseases. It is the set of rules and actions whose implementation contributes to the preservation, maintenance and protection of the health and comfort of individuals.” General good and bad practices are then illustrated, and key messages are presented on the benefits of optimal hygiene. The next lesson focuses on pathways and barriers to contamination, the relationship between poor hygiene and diseases, different transmission pathways, barriers to contamination, and the emergence of disease. Several chains of transmission of diseases in the case of poor hygiene are then illustrated, including open defecation, uncovered food, flies, and inadequate handwashing, among others. Good hygiene practices are then highlighted, including the use of latrines, handwashing, drinking clean water, and food protection. The next subtopic focuses on the diseases that result from poor hygiene and emphasizes that many common and deadly diseases in the community are linked to contaminated water, lack of hygiene, and interaction with livestock, including poultry. Different hygiene-related diseases and means of prevention are discussed, including (1) diarrhea, cholera, poliomyelitis, amebiasis, typhoid, and dysentery; (2) the transmission of diseases such as malaria, yellow fever, onchocerciasis (or river blindness) by mosquitoes and other insects that breed in dirty, stagnant water; (3) skin diseases such as scabies and mycoses; and (4) eye diseases such as conjunctivitis. Contamination from poultry droppings can cause diarrheal diseases, salmonellosis, and campylobacter.

Food- and Water-Related Hygiene

This session begins with content on hygiene as it relates to food preparation and handling. The trainer describes possible food contaminants related to unhygienic conditions that can cause disease. Several good practices are highlighted, including protecting food from flies and other insects, as well as ensuring that food utensils are washed thoroughly before use. The next subtopic introduces the role of water in the body, drinking water sources, and channels for water pollution/contamination. The content highlights a range of contaminants and high-risk practices, including human and animal feces, latrine construction close to wells or boreholes, household waste disposal, unprotected water storage and dispensing, and dirty hands. Possible water sources are then listed, alongside possible risks associated with different stages of water storage and use. The materials then highlight optimal water handling practices for supply, transport, storage, and consumption, including protecting water sources, washing storage containers with soap before use, emptying unused water from containers regularly, separating drinking water from water for other uses, washing hands with soap before handling water containers, and using appropriate containers for drinking water. Emphasis is then placed on water treatment, and several methods used for preparing drinking water are described. The last lesson of this session focuses on handwashing. The lesson describes its importance, the key moments for handwashing, and the different stages. "Good handwashing" is described as that undertaken using a sufficient amount of soap, rubbing hands together to create good friction, and rinsing under running water. Critical moments for hand washing with soap include after defecating; after cleaning a child's buttocks (or after contact with human excrement, including that of babies and children); before contact with food or water (before cooking or preparing food to eat, before giving food or water to the family, and before eating); before feeding a child; and before breastfeeding. Specific triggers for handwashing with soap also include any contact with livestock and chickens; cleaning poultry coops and caring for chickens; sweeping/cleaning the compound; returning from work or school; and using any chemicals. Where soap is not available, ash may be used as an alternative. The training session also illustrates examples of good practices in handwashing, including the construction of tippy taps.

Hygiene and the Environment

The last session of the SELEVER hygiene training module involves general hygiene in the compound, sanitation and safe disposal of feces, and managing feces from poultry and other livestock. The notion of hygiene in the context of everyday life in the compound is introduced. The materials highlight how a polluted environment can be a major determinant of ill health. Every day, households produce waste and garbage that can constitute real dangers if not managed appropriately. Some examples of household waste-management practices are presented, including collecting waste in covered trash cans and restricting the access of flies, insects, and other animals. The training materials then stress the need to understand the importance of safe feces disposal, highlighting that open defecation is a critical risk to household health, and then discuss context-appropriate sanitation options. The last lesson, on the management of poultry feces, highlights the pros and cons of different practices. Poultry breeding (in confined, semiconfined, or homeless mode) necessarily leads to the production of manure. The benefits of appropriate waste management include using chicken feces as a fertilizer to improve soil quality and water retention. Composting techniques are also mentioned. Lastly, the training highlights the health risks associated with exposure to poultry feces, with pregnant women and children most at risk. Practices such as leaving chicken feces in close proximity to children, or leaving children to play in areas where contamination with chicken feces is likely, are discouraged.

4. SECONDARY DATA ANALYSIS

Poultry Ownership in Burkina Faso

Poultry are the most commonly owned type of livestock in developing countries (Headey and Hirvonen 2016) and are particularly common in Africa south of the Sahara. Table 4.1 shows that across all African countries, Burkina Faso had the highest rate of poultry ownership, at 86 percent in rural areas and 43 percent in urban areas. However, Table 4.1 also reveals that consumption of poultry products is abysmally low, at just 3 percent for egg consumption in rural areas, and 4 percent for meat. Consumption of these products is marginally higher in urban areas but still very low. In other African countries, consumption of poultry products reported in the last 24 hours is also low, though often substantially higher in urban areas. Low consumption partly reflects the limitations of 24-hour recall—many children might consume egg or meat on a weekly basis but not on a daily basis—but it also likely reflects the relatively higher costs of eggs and poultry meat, especially given the limited scope for international trade in these products (particularly eggs) and the low productivity of domestic poultry production.

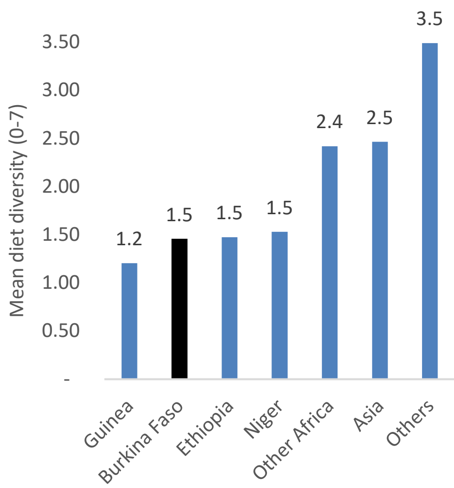
Table 4.1 Ownership of poultry and consumption of poultry products in African households

	Rural areas only			Urban areas only		
	Owns poultry	Ate eggs in last 24 hrs.	Ate meat in last 24 hrs.	Owns poultry	Ate eggs in last 24 hrs.	Ate meat in last 24 hrs.
Burkina Faso	86%	3%	4%	43%	5%	8%
Other Sahel	55%	3%	7%	24%	13%	20%
Coastal West Africa	49%	8%	10%	22%	14%	15%
Central Africa	37%	4%	8%	16%	7%	13%
Other Africa	63%	9%	13%	21%	14%	22%
All Africa	53%	7%	10%	21%	13%	18%

Source: Demographic Health Survey data.

Figure 4.1 shows that dietary diversity as a whole is very poor in Burkina Faso, ranking next to last among all DHS countries, at just 1.5 food groups. This is substantially lower than many other African countries and other developing regions included in the DHS. Notably, consumption of dairy products is also very low in Burkina Faso, with only 8 percent of children reporting consuming milk in the past 24 hours.

Figure 4.1 Dietary diversity scores (0–7) for the past 24 hours in Burkina Faso and other regions



Source: Demographic Health Survey data provided by the ARENA project.

Table 4.2 reports these same statistics by DHS wealth quintile for rural and urban areas. The results reveal why poultry ownership is so high in Africa: poultry rearing is widely regarded as a low-entry economic activity widely accessible to the poor. Nationally, poorer households are more likely to own poultry than richer households, though this partly reflects the strong association between wealth and urbanization. In rural areas poultry ownership rates scarcely differ across wealth quintiles, though wealthier households likely own much larger flocks. However, consumption of poultry products is positively correlated with wealth, with children from the richest quintile about twice as likely to consume eggs and meat products as children in the poorer quintiles. This suggests that poorer households are more likely to sell their poultry products rather than keep them for consumption by children.

Table 4.2 Ownership of poultry and consumption of poultry products across wealth quintiles in rural and urban areas of Burkina Faso

	Owns chicken	Ate eggs in last 24 hrs.	Ate meat in last 24 hrs.
All Burkina Faso			
Poorest	90%	4%	2%
Poorer	87%	2%	3%
Middle	84%	3%	3%
Richer	70%	3%	5%
Richest	35%	7%	9%
Rural areas only			
Poorest	90%	4%	2%
Poorer	87%	2%	3%
Middle	85%	3%	3%
Richer	76%	3%	5%
Richest	80%	6%	7%

Source: Faso and ICF International 2012.

Table 4.3 reports analogous statistics for major regions in Burkina Faso. Poultry ownership is relatively similar across regions, with the exception of more urbanized regions. Strikingly, egg and meat consumption is substantially higher in the Centre-Sud region, and to some extent in the Centre and Est regions. Egg and meat consumption is extremely low in some regions, notably in the Centre-Est, Centre-Nord, Nord, and Plateau Central. One explanation for these patterns may be that egg and meat productivity varies by regions, and partly by season.

Table 4.3 Poultry ownership and consumption of poultry products across major regions of Burkina Faso

	Owns chicken	Ate eggs in last 24 hrs.	Ate meat in last 24 hrs.
Boucle de Mouhoun	84%	4%	6%
Cascades	70%	5%	5%
Centre	33%	7%	8%
Centre-Est	76%	1%	2%
Centre-Nord	83%	1%	1%
Centre-Ouest	86%	3%	2%
Centre-Sud	85%	12%	10%
Est	92%	10%	6%
Hauts-Basins	59%	1%	5%
Nord	76%	1%	3%
Plateau Central	86%	1%	2%
Sahel	79%	0%	1%
Sud-Ouest	92%	3%	6%
Rural Burkina Faso	*85%*	*3%*	*4%*
Urban Burkina Faso	*33%*	*6%*	*7%*
All Burkina Faso	*77%*	*3%*	*4%*

Source: Faso and ICF International 2012.

WASH Conditions and Exposure to Livestock in Burkina Faso

Table 4.4 examines how various WASH indicators vary across Burkina Faso's regions. Overall toilet ownership rates in 2010 were extremely low, at just 22 percent on average. Ownership of toilets was highest in the Plateau Central and Centre regions. Access to piped or tube-well sources of drinking water varied more substantially, with 58 percent of households having access nationally. A roughly equal number (60 percent) can access water in less than 30 minutes, but this implies that a large proportion of the population has very poor access to water. Most households have a place to wash hands, but just under half actually have water at a handwashing place, with stark regional variation. Moreover, very few households practice any form of point-of-use water treatment.

Table 4.4 WASH conditions across major regions of Burkina Faso

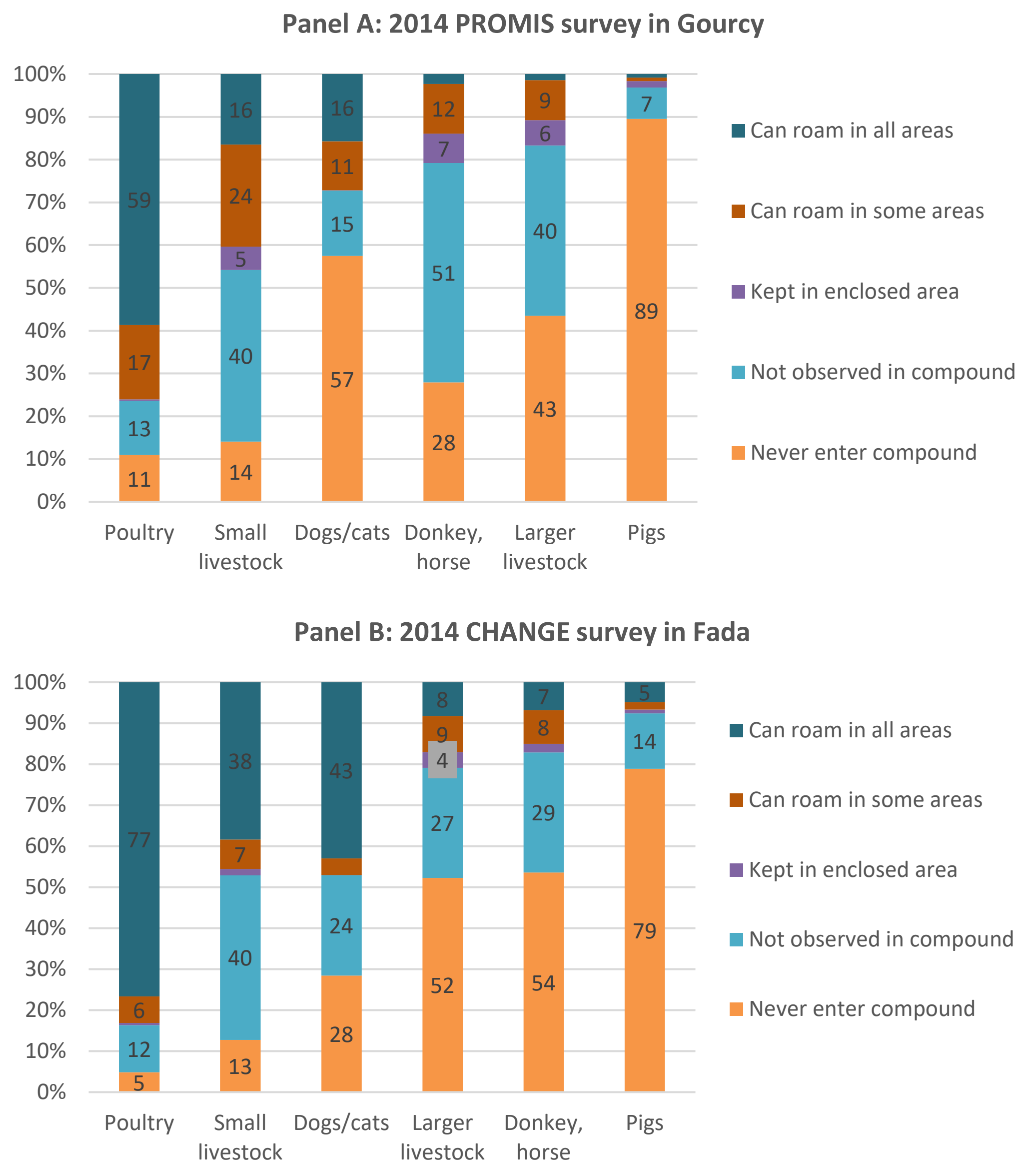
	Any toilet	Piped or tube well	Water <30 min.	Handwashing in place	Water at hand-washing place	Drinking water treated
Boucle de Mouhoun	31%	44%	69%	99%	35%	8%
Cascades	29%	71%	55%	100%	90%	10%
Centre	43%	90%	68%	92%	46%	4%
Centre-Est	8%	77%	53%	95%	63%	2%
Centre-Nord	20%	67%	55%	100%	42%	2%
Centre-Ouest	5%	51%	56%	78%	22%	12%
Centre-Sud	9%	76%	65%	78%	12%	2%
Est	2%	63%	61%	97%	84%	4%
Hauts-Basins	39%	57%	56%	98%	23%	5%
Nord	29%	44%	76%	75%	35%	19%
Plateau Central	44%	85%	70%	94%	60%	2%
Sahel	21%	40%	58%	82%	52%	23%
Sud-Ouest	3%	36%	70%	100%	40%	0%
All	*22%*	*58%*	*62%*	*92%*	*46%*	*7%*

Source: Faso and ICF International 2012.

Figure 4.2 examines the livestock dimension of WASH by reporting indicators of whether or not children may be exposed to livestock and/or livestock feces based on livestock mobility. Both the PROMIS and the CHANGE surveys reveal a similar pattern of results: the PROMIS survey reported that 59 percent of poultry could roam in all areas and a further 17 percent in some areas, while the CHANGE survey reported that 77 percent of poultry could roam freely, and a further 6 percent could roam in some areas. These ratios are generally substantially lower for other species, particularly small livestock, which is mainly goats. Given that some households may also not only own poultry or small ruminants, these ratios are very high, suggesting that exposure to animals and animal feces is extremely widespread.

Visible animal feces were reported in 84 percent of compounds in both the CHANGE and PROMIS surveys, while human feces were visible in 2 percent and 3 percent of compounds in the PROMIS and CHANGE surveys, respectively.

Figure 4.2 Potential exposure of young children to livestock among PROMIS and CHANGE survey respondents, 2014



Source: CHANGE and PROMIS baseline surveys.

In the CHANGE survey, only 2 percent of households had soap for handwashing anywhere in the household at the time of the baseline survey. Regarding sanitation, the vast majority of households did not have access to an improved sanitation facility. Four percent of households used latrines without slabs, but the common practice was open defecation (defecation in a field or in the bush) (87 percent). Sixty-nine percent of fathers and 62 percent of mothers stated that hands should be washed before eating, but only 14 percent of fathers and 21 percent of mothers stated that hands should be washed before feeding a child; only 18 percent of fathers and 32 percent of mothers cited “before cooking or preparing food” as a critical handwashing moment; and only 14 percent of fathers and 11 percent of mothers said that hands should be washed after defecation or urination. All three critical handwashing moments were correctly identified by only 3 percent of fathers and 4 percent of mothers.

5. PRIMARY DATA ANALYSIS

Household Observations

Household characteristics: Twenty caregiver-child pairs were observed for a total of 80 hours. Basic household characteristics in the study population are summarized in Table 5.1. All mothers were married, and only four of them (20 percent) had undertaken some formal primary education. Nearly all households owned a latrine, while only one household relied on using a neighbor's latrine. However, only one household (5 percent) had a handwashing station and soap. Thirteen households (65 percent) had access to running water, a borehole, or a protected well, whereas the remaining seven (35 percent) had access to an unprotected well. All households relied on a jerrican or clay pot for storing water.

Table 5.1 Maternal and household characteristics (n = 20) in three communities in Balés, Kossi, and Boulkiemdé provinces in Burkina Faso

Characteristic		Mean	S.D.
Number of households living within compound		2.3	2.2
Number of children living in household (restricted)		3.8	3.0
Number of children living in compound		4.9	5.2
		n	**(%)**
Caregiver gender	Female	20	(100)
Level of education	None	16	(80)
	Some primary	4	(20)
	Secondary	0	(0)
Marital status	Married	20	(100)
Latrine ownership	Own	19	(95)
	Latrine with compound	0	(0)
	Neighbor's	1	(5)
	Do not have	0	(0)
Latrine	Ventilated?	8	(40)
	Full?	0	(0)
Handwashing	Handwashing station	1	(5)
	Soap at handwashing station	1	(5)
Primary water sources	Public/communal tap water	4	(20)
	Borehole	4	(20)
	Protected well	5	(25)
	Unprotected well	7	(35)
	River	0	(0)
Drinking water	Barrel	0	(0)
	Jerrican	11	(55)
	Bucket	0	(0)
	Clay pot	9	(45)
Scooping container at point of use	Specific scooping cup	7	(35)
	Any cup/other	13	(65)

Source: SELEVER formative research.

General hygiene: One-quarter of mothers and 60 percent of children had hands that were visibly dirty at the beginning of the observation period (Table 5.2). Animals were present in 17 out of 20 households (85 percent), and chicken feces were present on the kitchen floor. In only 6 households (30 percent) was the kitchen yard swept. No human feces were observed, though chicken feces were present in all compounds. Chickens were observed roaming freely in the compound (mean n = 14, range 0–41), as were guinea fowl (mean n = 3, range 0–32). Other livestock were found in the compound, including goats, pigs, and cattle, both corralled and free to roam.

Table 5.2 General hygiene characteristics of infant's environment during observations (n = 20) in three communities in Balés, Kossi, and Boulkiemdé provinces in Burkina Faso

Characteristics	n	%
Caregiver's hands visibly dirty	5	(25)
Baby's hands visibly dirty	12	(60)
Diapers or child's bottom not clean	10	(50)
Stagnant water within infant's reach*	0	(0)
State of dwelling		
-Unwashed utensils	15	(75)
-Uncovered utensils	16	(80)
-Uncovered food	11	(55)
-Smooth concrete floor	1	(5)
-Dirt or cow dung floor	0	(0)
-Spill on floor (food or drink)	8	(40)
-Poultry feces visible on kitchen floor	20	(100)
-Animals in kitchen	17	(85)
State of compound		
-Kitchen yard swept	6	(30)
-Area where child plays is swept	6	(30)
-Poultry feces visible	20	(100)
-Human feces visible	0	(0)
-Other animal feces visible	19	(95)

Source: SELEVER formative research.
Note: *Any stagnant water within infant's reaches in kitchen or in compound.

Handwashing and diaper change practices: During the 80 hours of observation, mothers washed their hands 15 times out of 61 triggering opportunities (25 percent) (Table 5.3). Soap was used only three times. Mothers washed hands before eating 4 out of 9 times (44 percent) and before preparing food 4 out of 14 times (29 percent). Handwashing after toileting (2 out of 13 times, 15 percent) and after disposal of animal feces (0 out of 2 times) was low. Hands were air-dried on 12 out of the 15 handwashing occasions. Drying with a clean cloth was not observed.

Table 5.3 Mother's handwashing (n = 20) in three communities in rural Burkina Faso

Event	Opportunities	Any hand-washing		Handwashing with soap		Running water		Air-drying	
After agriculture work	1	1	(100)	0	(0)	0	(0)	1	(100)
After cleaning animal feces	2	0	(0)	0	(0)	0	(0)	0	(0)
After playing on floor	1	1	(100)	0	(0)	0	(0)	0	(0)
After sweeping	7	1	(14)	1	(14)	0	(0)	1	(14)
After toilet	13	2	(15)	1	(8)	0	(0)	2	(15)
Before eating	9	4	(44)	0	(0)	0	(0)	3	(33)
Before feeding child	10	1	(10)	0	(0)	0	(0)	0	(0)
Before food preparation	14	4	(29)	0	(0)	0	(0)	4	(29)
Whilst washing baby	1	1	(100)	1	(100)	0	(0)	1	(100)
Other	3	0	(0)	0	(0)	0	(0)	0	(0)

Source: SELEVER formative research.

During the 80 hours enumerators spent observing the 20 children, children's hands were also washed 15 times, including after playing on the floor (6 times), after eating (5 times), and before eating (4 times). Soap was used 3 times. Mothers washed their hands 6 out of the 13 times they cleaned their children after defecation, twice with soap. Out of the 13 times children defecated, feces were disposed in latrines 4 times (31 percent) and in garbage pits 3 times (23 percent). Feces were thrown in the yard once. In four cases, feces were ignored for more than 30 minutes and their disposal was not observed.

Frequency of infant-mouth contact: Objects identified as major fecal-oral vectors by frequency were food, children's hands or feet, water, food service utensils, and toys or play objects (Table 5.4). The objects that were mouthed were generally visibly dirty, with few exceptions. Mothers' or siblings' hands were not put into children's mouths during the observations. Wood or plastic collected from the ground was mouthed by 11 children. Chicken feces were not directly ingested by any of the observed children, but soil potentially contaminated with chicken feces was ingested by 9 (45%) children. Also of concern was that the majority of food given to children (79%) was visibly dirty.

Table 5.4 Potential fecal-oral vectors for children (n = 20) in three communities in Balés, Kossi, and Boulkiemdé provinces in Burkina Faso

Potential vector	No. of children	%	Mean episodes	S.D.	% visibly dirty	
Food	19	(95)	7.05	4.45	79	(95/121)
Baby's hands or feet	15	(75)	2.15	2.37	97	(29/30)
Baby's cup and spoon	13	(65)	1.45	1.36	82	(18/22)
Fruits	3	(15)	0.2	0.52	75	(3/4)
Toys	7	(35)	0.95	1.76	100	(12/12)
Mother's hands	0	(0)	0	0.00		
Soil	9	(45)	1.25	1.94	100	(10/10)
Mother's breasts	12	(60)	4.3	4.84	75	(63/84)
Sibling's hands	0	(0)	0	0.00		
Water	6	(30)	0.35	0.59	57	(4/7)
Stone	1	(5)	0.05	0.22	100	(1/1)
Chicken feces	0	(0)	0	0.00		
Wood	11	(55)	1.65	1.87	96	(22/23)
Plastic	11	(55)	1.55	2.28	95	(21/22)
Clothes	9	(45)	0.9	1.25	100	(7/7)
Pot, pan, buckets	10	(50)	0.8	1.01	100	(6/6)
Other	19	(95)	8.9	6.62	95	(59/62)

Source: SELEVER formative research.

Focus Group Discussions and In-Depth Observations and Interviews

In this section we summarize the main findings from the focus groups and in-depth interviews. Four focus groups discussions (two separate groups of men and women in two villages) were undertaken, including a total of 40 participants (18 women and 22 men). A total of 31 in-depth interviews were undertaken, of three volunteer vaccinators, three livestock extension workers, three community health workers, three district health officers, and 19 mothers of children ages 6 to 36 months. In the study villages, as in the general context of rural Burkinabe villages, household structures were organized in residential clusters of families ("enlarged households"). The enlarged households were generally structured in compounds including a number of ("restricted") households grouped around a courtyard.

Livestock were generally housed outside these compounds, though small animals were free to roam within the compound during the day. Poultry rearing was common in the study villages. Chickens roamed freely, scavenging for food, during the day and were housed in coops within the main compounds during the night. Children and poultry were often found sharing the same spaces, closely interacting on a regular basis. Women were generally charged with looking after both young children and chickens throughout the day. In this context, there were frequent opportunities for children to be exposed to chicken feces as the chickens roamed freely in the compound. Women were aware of children ingesting chicken feces and would sweep compounds to try to minimize this risk. However, the frequency of sweeping compounds was reported to vary considerably, with some households sweeping once or twice a day and others less than once a month, particularly during the main agricultural season. Chickens would also often be found pecking from plates that young children were being fed from, or from pots used to prepare meals (Figure 5.1).

Figure 5.1 Chickens scavenging in a household's food preparation area in rural Burkina Faso

Source: AFRICSante 2016.

Respondents participating in the in-depth interviews highlighted advantages of and risks from having children and chickens sharing the same space. The main advantage to having chickens roam freely was that it allowed chickens to find enough food to grow well and lay more eggs. The main disadvantage of chickens scavenging freely is that it increased the risk of children ingesting chicken feces or contaminated soil, leading to illnesses like diarrhea. In addition, free-range chickens were in some cases stolen, and had caused some arguments between neighbors. Most respondents identified the opportunity to separate children from chickens by improving poultry housing, though citing a "lack of means" as the main barrier to introducing this intervention. Several households in the study villages had been experimenting with local poultry housing solutions that could also serve as models for other producers. These examples were cited as opportunities to improve the level of general household hygiene and also reduce the risk of children ingesting poultry feces.

Though the usage of “WASH” as a specific term was not common, there was agreement among focus groups and in-depth interview respondents on the notion of hygiene as it related to general cleanliness of the body, food preparation and storage (including utensils for cooking and eating), drinking water, and the general environment. In addition, participants agreed on the importance of latrine use, alongside handwashing with soap after latrine use, and of safe drinking water. According to respondents, the villages had benefited from previous small-scale WASH interventions, including latrine construction and water improvement. However, little or no hygiene-related sensitization activities had taken place to date, and there was a consensus among participants of a need to improve the promotion of hygiene practices through community-based sensitization.

6. DISCUSSION

This formative research study was aimed at assessing the need for an intensive WASH and poultry-related hygiene intervention that could be rolled out alongside the SELEVER intervention in the context of the cluster RCT in Burkina Faso. We undertook primary and secondary research, combining both quantitative and qualitative methods, to address four key research questions focusing on characterizing (1) the extent of young children's exposure to poultry feces, (2) the general hygiene environment in rural households, (3) the extent of hygiene-related messaging within the SELEVER package, and (4) the scope for potential intensive WASH and livestock-related interventions. In this section we discuss the implications of the study findings, addressing each of the research questions in turn.

To What Extent Are Rural Burkinabe Children Exposed to Poultry Feces and Other Animal Feces?

The latest available DHS data, as well as the CHANGE and PROMIS surveys, indicate very high levels of poultry ownership across Burkina Faso. Chickens, and other small livestock, are allowed to roam freely throughout household compounds. Animal feces were visible in 84 percent of compounds observed in both the CHANGE and PROMIS surveys, suggesting that children's exposure to animals and animal feces is extremely widespread. Observations of children in rural households undertaken in this study confirmed frequent exposures to poultry, poultry feces, and soil. Children and poultry were often found sharing the same spaces and interacted closely on a regular basis. Chickens were seen feeding both from plates that young children were eating from and from pots used to prepare meals. In general, women were the primary caregivers for both young children and chickens, and they generally were aware of children ingesting chicken feces and would sweep compounds to try to minimize this risk. The frequency of sweeping the floor in compounds was found to vary considerably across households, with some households sweeping once or twice a day, and others less than once a month. The qualitative data also suggested that chickens were left to scavenge mainly in order to find enough food to grow well and increase egg production, allowing households to save on feed. Respondents were aware of the potential health risk that freely scavenging chickens posed to children in terms of ingesting feces or contaminated soil, a risk that in their view could potentially lead to illnesses like diarrhea. Other disadvantages of free-range chickens included theft, which had in some cases caused disturbances with neighbors.

What Are the General Hygiene Levels of Rural People in SELEVER Pilot Villages?

General hygiene levels in rural Burkina Faso are low. Overall toilet ownership rates reported in the DHS in 2010 were extremely low, at just 22 percent on average. Access to piped or tube-well sources of drinking water varied more substantially, with 58 percent of households having access nationally. A roughly equal number (60 percent) could access water in less than 30 minutes, implying that a large proportion of the population has very poor access to water. Most households have a place to wash hands, but just under half actually have water at a handwashing place, with stark regional variation. Moreover, very few households state that they do anything to treat their water.

Data from both CHANGE and the household observations confirmed the very low levels of optimal handwashing practices that could mitigate fecal-oral transmission of bacteria in children. Mothers' and children's hands were observed to be visibly dirty during the observation periods. Handwashing was rare for mothers, even after toileting and after disposal of animal feces, and for children. The very low use of soap after toileting (8 percent) was nearly identical to that observed in a similar study in Zimbabwe (Ngure et al. 2013). Children's feces were at times disposed of in latrines, though disposal in garbage pits or tossing out in the compound was also common. Children's feces were often ignored for long periods after defecation. Children frequently mouthed their hands or objects that were visibly dirty, while sharing the compound with livestock and poultry, thus likely causing frequent exposure to a range of potential pathogens as they played on the dirt floor. These findings contrast with responses from the in-depth interviews and focus groups, where respondents were aware of the notion of hygiene as it related to general cleanliness of the body, food preparation and storage (including utensils for cooking and eating), drinking water, and the general environment. Respondents also agreed on the importance of latrine use, alongside handwashing with soap after latrine use, and of safe drinking water. According to respondents, the villages had benefited from small-scale WASH interventions, including latrine construction and water improvement. However, little or no hygiene-related sensitization activities had taken place to date, and there was a consensus among participants of a need to improve the promotion of hygiene practices through community-based sensitization.

What Hygiene Messaging Is SELEVER Engaging in during Its Pilot Phase?

SELEVER has prepared a total of 14 training modules (8 for poultry, 3 for gender, and 3 for nutrition platforms) that will be scaled up as part of the intervention package. The content for the nutrition platform includes a specific module on hygiene. The hygiene training is expected to last three days and will be rolled out alongside the other SELEVER training packages using a cascade model. This involves the training of trainers, including ASI's NGO partners, who will then train the SELEVER beneficiaries. The training is aligned to SELEVER's approach of promoting the adoption of improved practices by providing key information on constraints and opportunities. Thus, the hygiene-related content focuses on the promotion of practical measures to improve WASH-related practices at the household level, including food preparation, use of water and sanitation, and waste management. No financial transfers or incentives are provided as part of the intervention. One lesson out of the nine included in the hygiene module focuses on management of poultry feces within the compound. The messaging on this topic includes the promotion of separate housing for poultry to minimize possible risks to children, as well as regular sweeping of the compound to remove poultry feces. As implementation of the hygiene training had not yet begun, it was not possible to gauge the knowledge transfer to participants.

What Is the Scope for the Project to Incorporate a More Intensive Livestock-Hygiene Component?

We reviewed the available evidence on the linkages between WASH practices, livestock ownership and corralling practices, and child nutrition outcomes, particularly in light of emerging evidence on livestock ownership and corralling practices as potential risk factors for child undernutrition. We hypothesized that livestock and WASH practices could influence child undernutrition through a number of different infection pathways, including diarrhea, EED, helminth infections, and other common childhood infections such as acute respiratory infections (ARIs) and malaria. We also hypothesized on a likely interaction between the effects of livestock and WASH practices, as optimal WASH (and other childcare practices) can serve as a potential barrier between animals and young children.

The findings on the proposed linkages between WASH practices, livestock practices, nutrition outcomes, and the intermediate pathways linking practices to nutrition outcomes highlight several important considerations. First, WASH interventions have substantial potential for improving child nutrition, though it is perhaps surprising that the evidence on their effectiveness is far from definitive. WASH interventions have strong impacts on diarrhea and STH infections, and perhaps some impact on ARIs, but the impact of these infections on child stunting is less clear. In contrast, measures of EED are associated with stunting, though this association is supported by limited observational evidence. However, there is no evidence of impacts of WASH interventions on EED, only limited evidence of WASH impacts on child stunting, and no experimental evidence on anemia. The RCT evidence on impacts of sanitation on stunting has several methodological limitations, however, which may obscure its true impacts and explain why observational studies tend to find much stronger associations between toilet use and stunting. Second, there is emerging evidence that hazardous livestock practices in low-income countries—including corralling poultry close to children at night and not separating poultry and other livestock from areas where children sit, crawl, play, and eat—may be strongly associated with EED and stunting, though the evidence is limited to observational studies. There is also suggestive evidence that livestock ownership, particularly poultry ownership, may be a more common risk factor for diarrhea than previously thought. Poultry are also an important reservoir for avian flu and may be a risk factor for respiratory infections in young children, although there is surprisingly little research on this topic. There is also evidence that keeping livestock close to the home can increase the risk of malaria transmission. There is limited evidence linking malaria or ARIs to nutrition outcomes, although there are plausible biological mechanisms.

Implications for Intervention Design

The lack of a consistent impact of WASH interventions reported in the literature review highlights the need to know how such interventions might be improved. Three out of five recent RCTs on CLTS, sanitation marketing, and subsidies on sanitation supplies did not show an impact on child linear growth. This could likely be due to the short exposure to the intervention and the need to target children earlier in the first thousand days of life, but also to the lack of a substantive behavioral change communications emphasis in several of the trials (Headey 2016). The most notable exception among the five RCTs was the Mali evaluation implemented by Pickering et al.(2015). This intervention involved an intensive CLTS campaign implemented over the course of a year, with monthly visits, which resulted in a 33 percent reduction in open defecation.

CLTS triggers behavior change at the community level, which is regarded as essential because of the implicit assumption that cultural norms and ignorance of the dangers of open defecation are the primary obstacles to the adoption of toilets (Chambers et al. 2015; Kar 2003). Behavioral change might also encourage the adoption of complementary hygiene behaviors such as handwashing and water treatment. In contrast, several studies have argued that financial and supply-side constraints are also important (Cameron and Shah 2013; Gertler et al. 2015); one cluster RCT in Bangladesh found that CLTS and marketing interventions had no impact on toilet adoption, while subsidies to the landless poor increased adoption by 22 percentage points. A recent meta-analysis of latrine adoption found more complex results (Garn et al. 2016). It found few differences in reported latrine expansion among subsidy or provision interventions (16%; 95% CI: 8%, 24%), latrine subsidy or provision interventions that also incorporated education components (17%; 95% CI: -5%, 38%), sewerage interventions (14%; 95% CI: 1%, 28%), sanitation education interventions (14%; 95% CI: 3%, 26%), and CLTS interventions (12%; 95% CI: -2%, 27%). It also reported the expected result that better maintenance, accessibility, privacy, facility type, cleanliness, newer latrines, and better hygiene access were all frequently associated with higher use, whereas poorer sanitation conditions were associated with lower use. It is likely that the optimal WASH intervention is highly context-specific, depending on where households are in the sanitation ladder (e.g., moving away from pervasive open defecation versus upgrading from pit latrines to improved latrines), on socioeconomic status and overall resource constraints, and on levels of hygiene knowledge and cultural norms.

Yet although improving WASH conditions is a necessary condition for reducing childhood infections and improving nutrition outcomes, we argue that it is unlikely to be a sufficient condition because conventional WASH interventions do not address inadequate animal husbandry and childcare practices. Evidence reported in the review section of this report indicates that animal feces contamination is likely more widespread than human feces contamination in low-income contexts (Headey and Hirvonen 2016 Headey et al. 2016), where free-scavenging poultry and livestock farming is common, and that children are highly likely to ingest poultry feces in contexts as diverse as Peru (Marquis et al. 1990), Zimbabwe (Ngure et al. 2013), Ethiopia (Save the Children/Ethiopia and Manoff Group 2014), Bangladesh (George, Oldja, Biswas, Perin, Lee, Ahmed, et al. 2015), and Zambia (Brie et al. 2017. The current evidence-based WASH interventions are not sufficient to protect children under the age of 24 months from ingestion of contaminated soil and animal feces (Ngure et al. 2013; Ngure et al. 2014). Effective child-oriented WASH interventions to cover the first thousand days of life will require additional technological inputs and behavior change interventions to provide a hygienic feeding and play environment. The ongoing SHINE trial in Zimbabwe has already demonstrated that the use of a clean play space is feasible and acceptable when mothers are educated on the dangers of soil and animal feces ingestion (Brie et al. 2017; Mbuya et al. 2015).

It is somewhat less clear how much can be done within the livestock space. Promoting improved housing, feeding, and healthcare of poultry and livestock seemingly has great potential to both improve the productivity of livestock rearing (because the livestock themselves suffer from EED and infectious diseases related to poor hygiene) and reduce the transmission of zoonotic diseases via animal feces or other disease vectors.

There is scant literature on interventions to reduce health risks from poor animal husbandry practices, but there are likely several types of constraints on the adoption of improved livestock housing and hygiene.

The first relates to financial and time constraints. In an observation study on poultry farming in a Peruvian shantytown, researchers implemented a two-month trial on the use of corrals, and most of the participants were willing to keep birds in a corral more often after extensive orientation and technical assistance (Harvey et al. 2003). However, scavenging poultry systems save time and money because the poultry find their own feed, especially during the harvest season when scavenging opportunities are more plentiful. Corralling poultry requires household members to provide adequate feed, as well as water, in addition to the time costs associated with bird care and corral hygiene. In the SHINE study in Zimbabwe, surveyed households were also resistant to corralling poultry during the day, citing feed constraints as the major factor (Mbuya et al. 2015; Ngure et al. 2013). Such challenges are common in other rural contexts where small-scale production is characterized by low-input/low-output scavenging, with minimal investment in housing, feeding, and healthcare, and consequently weak biosecurity and high disease and mortality rates (Dessie et al. 2013).

A second constraint is lack of knowledge of the potential impact of poor livestock hygiene on the health, nutrition, and development of young children. In the Peru study (Harvey et al. 2003) most participants viewed bird feces in the house and yard as dirty, but few people saw a connection with illness. Indeed, if anything, participants claimed that free-range birds were healthier and happier and produced better-quality meat and eggs. Similar findings were observed in formative research in Ethiopian villages (Save the Children/Ethiopia and Manoff Group 2014). It may also be the case that households lack knowledge of how and where to build improved poultry housing.

A third constraint, particularly on the construction of poultry houses more removed from the household's sleeping and food preparation areas, is fear of theft and predation (Headey and Hirvonen 2016; Save the Children/Ethiopia and Manoff Group 2014).

These findings suggest that while behavior change communication strategies may be essential for addressing knowledge constraints regarding the importance and practical approaches to more hygienic livestock management, there may well be financial and logistical constraints on adoption of a broader set of improved livestock practices, including management of feed, water, and cleaning, and construction of improved poultry housing.

In Table 6.1 we present a matrix to support the design of appropriate and feasible interventions for improving both conventional WASH practices and WASH practices specific to animal and child interactions. Our review of the literature on WASH interventions suggests that conventional interventions pay limited attention to child-specific WASH practices, including exposure to animals and animal feces, and adequate disposal of child and animal feces. Thus, in addition to standard WASH interventions (CLTS, sanitation subsidies and/or marketing, handwashing promotion, water treatment, and hygiene messaging), reducing infection among small children requires more unconventional interventions to limit contact between animals and children. However, the most effective way to promote barriers between children and animals is an under-researched issue, and likely context-specific. As noted above, lack of awareness of the risks of poor animal-related hygiene is a major constraint, but the separation of animals and children likely involves significant financial and opportunity costs. Relatively poor and uncommercialized livestock producers are likely to resist corralling animals on a permanent basis because of the costs of constructing poultry housing and providing feed and water. While more comprehensive improvement of poultry management may be feasible for more commercialized poultry producers, poor households may need to focus more on separating the children from animals through other means (separate child play spaces, communal child care facilities, more frequent sweeping, and improved disposal of child feces). These hypotheses are clearly conjectural. Much more research is needed on the constraints on adopting more child-sensitive WASH practices; how effective different practices are in reducing bacterial loads, EED, and infection rates; and whether these interventions ultimately make a substantial impact on child nutrition and cognitive development.

Table 6.1 Potential interventions for achieving comprehensive animal- and child-sensitive WASH practices

	Poor conventional WASH practices (lack of toilets, soap, and improved water; dirty compound; and high presence of animal feces)	**Improved conventional WASH practices** (toilets, soap, water, clean compound, and minimal animal feces)
Semi-commercialized livestock producers (small subsistence livestock systems, scavenging feeding systems, unimproved housing, limited use of modern inputs)	Address deficiencies in conventional WASH practices: • CLTS, sanitation subsidies, and/or marketing • Handwashing promotion • Point-of-use water treatment • Food hygiene messages • Promotion of appropriate disposal of child feces Address deficiencies in animal and child WASH practices: • Promotion of appropriate disposal of animal feces • Assessment of demand for improved poultry housing • Assessment of demand for improved poultry management (feed, water, hygiene, and other modern inputs) • Assessment of options for separate child play spaces • Assessment of potential for hygienic child care facilities	Address outstanding deficiencies in conventional WASH practices (see column 1) and move up the WASH ladder. Address outstanding deficiencies in animal and child WASH practices (see column 1).
Commercialized livestock producers (large herds and flocks, improved housing, greater demand for modern inputs and husbandry techniques)	Address deficiencies in conventional WASH practices. Address deficiencies in animal and child WASH practices. Additional focus on: • Promotion of improved animal housing, feed, water, and use of modern inputs • Improved animal hygiene	Address outstanding deficiencies in conventional WASH practices (see column 1). Address outstanding deficiencies in animal and child WASH practices (see column 1). Additional focus on: • Promotion of improved animal housing, feed, water, and use of modern inputs • Improved animal hygiene

Source: Authors.
Note: CLTS = community-led total sanitation; WASH = water, sanitation, and hygiene.

7. CONCLUDING REMARKS

The findings of this study confirm that the general WASH environment, including knowledge, practices, and infrastructure, in rural Burkina Faso is remarkably limited. In parallel, poultry production is ubiquitous and, as commonly practiced in rural Burkinabe settings, results in an environment that may be hazardous to the health of young children. These findings suggest the opportunity to develop a two-layered WASH and poultry-related intervention, integrating a CLTS-type approach that tackles community- and household-level WASH constraints alongside a poultry-hygiene-specific behavior change communication component. Emerging evidence suggests that exposure to animal feces is a significant health risk; however, it is still unclear how this risk can be mitigated programmatically. In the context of SELEVER, this would entail increasing poultry and egg production (and consumption) while concomitantly reducing children's exposure to poultry feces. Scaling up an intensive SELEVER+WASH package alongside the standard SELEVER intervention in the context of the randomized trial would provide rigorous, policy-relevant evidence in this emerging field.

REFERENCES

Adair, L. S., and D. K. Guilkey. 1997. "Age-specific Determinants of Stunting in Filipino Children." *The Journal of Nutrition* 127 (2): 314–320. http://www.ncbi.nlm.nih.gov/pubmed/9039833.

Aiello, A. E., R. M. Coulborn, V. Perez, and E. L. Larson. 2008. "Effect of Hand Hygiene on Infectious Disease Risk in the Community Setting: A Meta-analysis." *American Journal of Public Health* 98 (8) 1372–1381. https://doi.org/10.2105/AJPH.2007.124610.

Akitoye, O. C., D. I. Raphael, N. T. Bolaji, O. A. Kehinde, and C. L. Obi. 2002. "Human Campylobacteriosis in Developing Countries." Emerging Infectious Disease Journal 8 (3): 237.

Ashraf, S., Huque, M. H., Kenah, E., Agboatwalla, M., and Luby, S. P. (2013). Effect of recent diarrhoeal episodes on risk of pneumonia in children under the age of 5 years in Karachi, Pakistan. International Journal of Epidemiology, 42(1), 194–200. https://doi.org/10.1093/ije/dys233

ATS (American Thoracic Society). 1998. "Respiratory Health Hazards in Agriculture." American Journal of Respiratory and Critical Care Medicine 158 (S1): S1–S76.

Bender JB, S. S. A. in P. C. subcommittee; N. A. of S. P. H. V. (2004). Reports of zoonotic disease outbreaks associated with animal exhibits and availability of recommendations for preventing zoonotic disease transmission from animals to people in such settings. J Am Vet Med Assoc., 224(7), 1105–9. https://doi.org/15074855

Bhutta, Z. a, Ahmed, T., Black, R. E., Cousens, S., Dewey, K., Giugliani, E., … Shekar, M. (2008). What works? Interventions for maternal and child undernutrition and survival. Lancet, 371(9610), 417–40. https://doi.org/10.1016/S0140-6736(07)61693-6

Black, R. E., Victora, C. G., Walker, S. P., Qar, Z., Bhutta, A., Christian, P., … Uauy, R. (2013). Maternal and Child Nutrition 1 Maternal and child undernutrition and overweight in low-income and middle-income countries. Www.Thelancet.Com, 382(3). https://doi.org/10.1016/S0140-6736(13)60937-X

Briceño, B., Aidan, C., & Martinez, S. (2014). Promoting Handwashing and Sanitation: A Crossover Randomized Experiment in Rura Tanzania. Water and Sanitation Program, World Bank. Washington, DC:

Brie, R., Rie, S., Jennifer, O., Khrist, R., Catherine, P., Modesta, C., … Rebecca Stoltzfus. (2017). A community-designed play-yard intervention to prevent microbial ingestion: A Baby WASH pilot study in rural Zambia. Unpublished.

Cairncross, S., Hunt, C., Boisson, S., Bostoen, K., Curtis, V., Fung, I. C., & Schmidt, W. P. (2010). Water, sanitation and hygiene for the prevention of diarrhoea. International Journal of Epidemiology, 39(Supplement 1), i193–i205. https://doi.org/10.1093/ije/dyq035

Cameron, L., Shah, M., & Olivia, S. (2013). Impact Evaluation of a Large-Scale Rural Sanitation Project in Indonesia, The World(February).

Campbell DI, McPhail G, Lunn PG, Elia M, & Jeffries DJ. (2004). Intestinal inflammation measured by fecal neopterin in Gambian children. Journal of Pediatric Gastroenterology & Nutrition, 39(2), 153–157.

Campbell, D. I., Elia, M., & Lunn, P. G. (2003). Growth faltering in rural Gambian infants is associated with impaired small intestinal barrier function, leading to endotoxemia and systemic inflammation. J Nutr. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12730419

CFS (Committee on World Food Security). 2014. Principles for Responsible Investment in Agriculture and Food Systems. Rome: CFS.

Checkley, W., Buckley, G., Gilman, R. H., Assis, A. M., Guerrant, R. L., Morris, S. S., … Black, R. E. (2008). Multi-country analysis of the effects of diarrhoea on childhood stunting. International Journal of Epidemiology, 37(4), 816–30. https://doi.org/10.1093/ije/dyn099

Checkley, W., Gilman, R. H., Black, R. E., Epstein, L. D., Cabrera, L., Sterling, C. R., & Moulton, L. H. (2004). Effect of water and sanitation on childhood health in a poor Peruvian peri-urban community. Lancet, 363(9403), 112–118. https://doi.org/10.1016/S0140-6736(03)15261-0

Coffey, D., M. Geruso, and D. Spears. 2016. Sanitation, Disease Externalities, and Anemia: Evidence from Nepal. Working Paper Series 22940. Cambridge, MA, US: National Bureau of Economic Research.

Crompton, D. W. T., & Nesheim, M. C. (2002). Nutritional impact of intestinal helminthiasis during the human life cycle. Annual Review of Nutrition, 22, 35–59. https://doi.org/10.1146/annurev.nutr.22.120501.134539

Curtis, V., S. Cairncross, and R. Yonli. 2000. “Domestic Hygiene and Diarrhoea: Pinpointing the Problem.” Tropical Medicine and International Health 5 (1): 22–32.

Dangour, D., Watson, L., Cumming, O., Boisson, S., Che, Y., Velleman, Y., … 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 Syst Rev, 8(8), CD009382. https://doi.org/10.1002/14651858.CD009382.pub2

Dessie, T., Esatu, W., Waaij, L. Vander, Zegeye, F., Gizaw, S., Mwai, O., & Arendonk, J. Van. (2013). Village chicken production in the central and western highlands of Ethiopia: Characteristics and strategies for improvement. International Livestock Research Institute, Nairobi, Kenya.

Dewey , K. G., and S. Adu-Afarwuah. 2008. “Systematic Review of the Efficacy and Effectiveness of Complementary Feeding Interventions in Developing Countries.” Maternal and Child Nutrition 1: 24–85.

DFID. (2013). Water, Sanitation and Hygiene, (May).

Donnelly, B., L. Berrang-Ford, N. A. Ross, and P. Michel. 2015. “A Systematic, Realis(Ngure et al., 2013)t Review of Zooprophylaxis for Malaria Control.” Malaria Journal 14: 313.

Dreibelbis, R., Kroeger, A., Hossain, K., Venkatesh, M., & Ram, P. (2016). Behavior Change without Behavior Change Communication: Nudging Handwashing among Primary School Students in Bangladesh. International Journal of Environmental Research and Public Health, 13(1), 129. https://doi.org/10.3390/ijerph13010129

Eisele, T. P., D. A. Larsen, P. A. Anglewicz, J. Keating, J. Yukich, A. Bennett, P. Hutchinson, and R. W. Steketee. 2012. “Malaria Prevention in Pregnancy, Birthweight, and Neonatal Mortality: A Meta-analysis of 32 National Cross-sectional Datasets in Africa.” Lancet Infectious Diseases 12 (12): 942–949.

Ejemot, R. I., Ehiri, J. E., Meremikwu, M. M., & Critchley, J. A. (2008). Hand washing for preventing diarrhoea. The Cochrane Database of Systematic Reviews, (1), CD004265. https://doi.org/10.1002/14651858.CD004265.pub2

Esrey, S. a. (1996). Water, waste, and well-being: a multicountry study. American Journal of Epidemiology, 143(6), 608–23. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/8610678

FAO (Food and Agriculture Organization). 2011. Rural Households’ Livelihood and Well-Being Statistics on Rural Development and Agriculture Household Income. Rome.

FAO (Food and Agriculture Organization of the United Nations). 2013. Milk and Dairy Products in Human Nutrition. Rome: FAO.

Faso, I. B., and ICF International. 2012. Enquête Démographique et de Santé et à Indicateurs Multiples du Burkina Faso 2010. Calverton, MA, US: Institut National de la Statistique et de la Démographie (INSD) and ICF International.

Fewtrell, L., Kaufmann, R. B., Kay, D., Enanoria, W., Haller, L., & Colford, J. M. (2005). Water, sanitation, and hygiene interventions to reduce diarrhoea in less developed countries: a systematic review and meta-analysis. The Lancet. Infectious Diseases, 5(1), 42–52. https://doi.org/10.1016/S1473-3099(04)01253-8

Fink, G., Günther, I., & Hill, K. (2011). The effect of water and sanitation on child health: evidence from the demographic and health surveys 1986-2007. International Journal of Epidemiology, 40(5), 1196–204. https://doi.org/10.1093/ije/dyr102

Fink, G., I. Günther, and K. Hill. 2011. “The Effect of Water and Sanitation on Child Health: Evidence from the Demographic and Health Surveys 1986–2007.” International Journal of Epidemiology 40 (5): 1196–1204.

Friis, H., Mwaniki, D., Omondi, B., Muniu, E., Thiong'o, F., Ouma, J., … P.W., G. (2003). Effects on haemoglobin of multi-micronutrient supplementation and multi-helminth chemotherapy: A randomized, controlled trial in Kenyan school children. European Journal of Clinical Nutrition, 57(4), 573–579. https://doi.org/DOI 10.1038/sj.ejcn.1601568

Garn, J. V., & et al. (2016). The impact of sanitation interventions on latrine coverage and latrine use:Asystematic review and meta-analysis. Int. J. Hyg. Environ. Health, 2027(November). Retrieved from http://www.sciencedirect.com/science/article/pii/S1438463916302619

George, C. M., L. Oldja, S. K. Biswas, J. Perin, G. O. Lee, S. Ahmed, R. Haque, R. B. Sack, T. Parvin, I. J. Azmi, S. I. Bhuyian, K. A. Talukder, and A. G. Faruque. 2015. "Fecal Markers of Environmental Enteropathy Are Associated with Animal Exposure and Caregiver Hygiene in Bangladesh." American Journal of Tropical Medicine Hygiene 93 (2): 269–275.

George, C. M., Oldja, L., Biswas, S., Perin, J., Lee, G. O., Kosek, M., … Faruque, A. G. (2015). Geophagy is associated with environmental enteropathy and stunting in children in rural Bangladesh. American Journal of Tropical Medicine and Hygiene, 92(6), 1117–1124. https://doi.org/10.4269/ajtmh.14-0672

George, C. M., Oldja, L., Biswas, S., Perin, J., Sack, R. B., Ahmed, S., … Faruque, A. G. (2016). Unsafe Child Feces Disposal is Associated with Environmental Enteropathy and Impaired Growth. The Journal of Pediatrics, 176, 43–9. https://doi.org/10.1016/j.jpeds.2016.05.035

Gertler, P., Shah, M., Alzua, M., & Cameron, L. (2015). How Does Health Promotion Work? Evidence from the Dirty Business of Eliminating Dirty Defecation. Retrieved from https://escholarship.org/uc/item/8b17z49c.pdf

Gomaa, M. R., A. S. Kayed, M. A. Elabd, D. A. Zeid, S. A. Zaki, A. S. El Rifay, L. S. Sherif, P. P. McKenzie, R. G. Webster, R. J. Webby, M. A. Ali, and G. Kayali. 2015. "Avian Influenza A(H5N1) and A(H9N2) Seroprevalence and Risk Factors for Infection among Egyptians: A Prospective, Controlled Seroepidemiological Study." Journal of Infectious Diseases 211 (9): 1399–1407.

Goto, R., Mascie-taylor, C. G. N., & Lunn, P. G. (2009). Impact of intestinal permeability , inflammation status and parasitic infections on infant growth faltering in rural Bangladesh British Journal of Nutrition, 1509–1516. https://doi.org/10.1017/S0007114508083554

Guerrant, R. L., Leite, A. M., Pinkerton, R., Medeiros, P. H. Q. S., Cavalcante, P. A., DeBoer, M., … Lima, A. A. M. (2016). Biomarkers of Environmental Enteropathy, Inflammation, Stunting, and Impaired Growth in Children in Northeast Brazil. Plos One, 11(9), e0158772. https://doi.org/10.1371/journal.pone.0158772

Guyatt, H. L., and R. W. Snow. 2004. "Impact of Malaria during Pregnancy on Low Birth Weight in Sub-Saharan Africa." Clinical Microbiology Reviews 17 (4): 760–769.

Harvey, S. a, Winch, P. J., Leontsini, E., Torres Gayoso, C., López Romero, S., Gilman, R. H., & Oberhelman, R. a. (2003). Domestic poultry-raising practices in a Peruvian shantytown: implications for control of Campylobacter jejuni-associated diarrhea. Acta Tropica, 86(1), 41–54. https://doi.org/10.1016/S0001-706X(03)00006-8

Hathi, P., S. Haque, L. Pant, D. Coffey, and D. Spears. 2014. Place and Child Health: The Interaction of Population Density and Sanitation in Developing Countries. Policy Research Working Paper Series 7124. Washington, DC: World Bank.

Headey, D. (2012). Agriculture , Income , and Nutrition Linkages in India Insights from a Nationally Representative Survey, (July).

Headey, D. 2016. "Are Studies Underestimating the Effects of Sanitation on Child Nutrition?" Lancet Global Health 4 (3): e159.

Headey, D. D., and J. Hoddinott. 2015. "Understanding the Rapid Reduction of Undernutrition in Nepal, 2001–2011." PLoS ONE 10 (12): e0145738.

Headey, D., & Hirvonen, K. (2016). Is exposure to poultry harmful to child nutrition? An observational analysis for rural Ethiopia. PLoS ONE, 11(8), 1–16. https://doi.org/10.1371/journal.pone.0160590

Headey, D., J. Hoddinott, and S. Park. 2016. “Drivers of Nutritional Change in Four South Asian Countries: A Dynamic Observational Analysis.” Maternal and Child Nutrition 12: 210–218.

Headey, D., J. Hoddinott, D. Ali, R. Tesfaye, and M. Dereje. 2015. “The Other Asian Enigma: Explaining the Rapid Reduction of Undernutrition in Bangladesh.” World Development 66: 749–761.

Headey, D., P. Nguyen, S. Kim, R. Rawat, M. Ruel, and P. Menon. 2016. “Is Exposure to Animal Feces Harmful to Child Nutrition and Health Outcomes? A Multicountry Observational Analysis.” American Journal of Tropical Medicine and Hygiene, forthcoming .

Herforth, A., and S. Ahmed. 2015. “The Food Environment, Its Effects on Dietary Consumption, and Potential for Measurement within Agriculture-Nutrition Interventions.” Food Security 7 (3): 505–520.

Humphrey, J. H. 2009. “Child Undernutrition, Tropical Enteropathy, Toilets, and Hand Washing.” Lancet 374 (9694): 1032–1035.

Humphrey, J. H., Jones, A. D., Manges, A., Mangwadu, G., Maluccio, J. A., Mbuya, M. N. N., … Mujuru, H. A. (2015). The sanitation hygiene infant nutrition efficacy (SHINE) Trial: Rationale, design, and methods. Clinical Infectious Diseases, 61(Suppl 7), S685–S702. https://doi.org/10.1093/cid/civ844

Huybregts, L., E. Becquey, A. Zongrone, et al . 2017. “The Impact of Integrated Prevention and Treatment on Child Malnutrition and Health: The PROMIS Project, a Randomized Control Trial in Burkina Faso and Mali.” BMC Public Health 17: 237. doi:10.1186/s12889-017-4146-6.

Iannotti, L. L., C. K. Lutter, D. A. Bunn, and C. P. Stewart. 2014. “Eggs: The Uncracked Potential for Improving Maternal and Young Child Nutrition among the World’s Poor.” Nutrition Reviews 72 (6): 355–368.

Iannotti, L., E. Muehlhoff, and D. McMahon. 2013. “Review of Milk and Dairy Programmes Affecting Nutrition.” Journal of Development Effectiveness 5 (1): 82–115.

Jaleta, K. T., S. R. Hill, G. Birgersson, H. Tekie, and R. Ignell. 2016. “Chicken Volatiles Repel Host-Seeking Malaria Mosquitoes.” Malaria Journal 15 (1): 1–9.

Jelkmann, W., Wolff, M., & Fandrey, J. (1989). Modulation of the production of erythropoietin by cytokines: in vitro studies and their clinical implica- tions. In Contrib Nephrol (p. 87:68-77).

Karesh WB, Dobson A, Lloyd-Smith JO, Lubroth J, Dixon MA, Bennett D, Aldrich S, Harrington T, Formenty P, Loh EH, et al. Ecology of zoonoses: natural and unnatural histories. Lancet. 2012;380(9857):1936–45.

Kaur, M., J. P. Graham, and J. N. S. Eisenberg. 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).” American Journal of Tropical Medicine and Hygiene, forthcoming.

Khuntirat, B. P., I.-K. Yoon, P. J. Blair, W. S. Krueger, M. Chittaganpitch, S. D. Putnam, K. Supawat, R. V. Gibbons, S. Pattamadilok, P. Sawanpanyalert, G. L. Heil, J. A. Friary, A. W. Capuano, and G. C. Gray. 2011. “Evidence for Subclinical Avian Influenza Virus Infections among Rural Thai Villagers.” Clinical Infectious Diseases 53 (8): e107–e116.

Korpe, P. S., and W. A. Petri Jr. 2012. “Environmental Enteropathy: Critical Implications of a Poorly Understood Condition.” Trends in Molecular Medicine 18 (6): 328–336.

Kosek, M., Haque, R., Lima, A., Babji, S., Shrestha, S., Qureshi, S., … Gottlieb, M. (2013). Fecal markers of intestinal inflammation and permeability associated with the subsequent acquisition of linear growth deficits in infants. The American Journal of Tropical Medicine and Hygiene, 88(2), 390–6. https://doi.org/10.4269/ajtmh.2012.12-0549

Leung, D. T., Das, S. K., Malek, M. A., Faruque, A. S. G., Qadri, F., Chisti, M. J., & Ryan, E. T. (2015). Concurrent pneumonia in children under 5 years of age presenting to a diarrheal hospital in Dhaka, Bangladesh. American Journal of Tropical Medicine and Hygiene, 93(4), 831–835. https://doi.org/10.4269/ajtmh.15-0074

Lin, A., Arnold, B. F., Afreen, S., Goto, R., Huda, T. M. N., Haque, R., … Luby, S. P. (2013). Household environmental conditions are associated with enteropathy and impaired growth in rural Bangladesh. The American Journal of Tropical Medicine and Hygiene, 89(1), 130–7. https://doi.org/10.4269/ajtmh.12-0629

Lind, T., Lonnerdal, B., Stenlund, H., Gamayanti, I. L., Ismail, D., Seswandhana, R., & Persson, L. A. (2003). A community-based randomized controlled trial of iron and zinc supplementation in Indonesian infants: interactions between iron and zinc. American Journal of Clinical Nutrition, 77, 883–90.

Liu, B., F. Havers, E. Chen, Z. Yuan, H. Yuan, J. Ou, M. Shang, K. Kang, K. Liao, F. Liu, D. Li, H. Ding, L. Zhou, W. Zhu, F. Ding, P. Zhang, X. Wang, J. Yao, N. Xiang, S. Zhou, X. Liu, Y. Song, H. Su, R. Wang, J. Cai, Y. Cao, X. Wang, T. Bai, J. Wang, Z. Feng, Y. Zhang, M.-A. Widdowson, and Q. Li. 2014. "Risk Factors for Influenza A(H7N9) Disease—China, 2013." Clinical Infectious Diseases 59 (6): 787–794.

Lunn, P. G. (2000). The impact of infection and nutrition on gut function and growth in childhood. Proceedings of the Nutrition Society, 59(1), 147–154. https://doi.org/10.1017/S0029665100000173

Lunn, P., Northrop-Clewes, C., & Downes, R. (1991). Intestinal permeability, mucosal injury and growth faltering in Gambian infants. Lancet, (338), 907–910.

Mara, D., Lane, J., Scott, B., & Trouba, D. (2010). Sanitation and health. PLoS Medicine, 7(11), e1000363. https://doi.org/10.1371/journal.pmed.1000363

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. https://doi.org/10.2105/AJPH.80.2.146

Masset, E., L. Haddad, A. Cornelius, and J. Isaza-Castro. 2011. "Effectiveness of Agricultural Interventions That Aim to Improve Nutritional Status of Children: A Systematic Review." British Medical Journal 344: d8222.

Mbuya, M. N. N., and J. H. Humphrey. 2016. "Preventing Environmental Enteric Dysfunction through Improved Water, Sanitation and Hygiene: An Opportunity for Stunting Reduction in Developing Countries." Maternal and Child Nutrition 12: 106–120.

Mbuya, M. N. N., Tavengwa, N. V., Stoltzfus, R. J., Curtis, V., Pelto, G. H., Ntozini, R., … Humphrey, J. H. (2015). Design of an intervention to minimize ingestion of fecal microbes by young children in Rural Zimbabwe. Clinical Infectious Diseases, 61(Suppl 7), S703–S709. https://doi.org/10.1093/cid/civ845

Merchant, a T., Jones, C., Kiure, a, Kupka, R., Fitzmaurice, G., Herrera, M. G., & Fawzi, W. W. (2003). Water and sanitation associated with improved child growth. European Journal of Clinical Nutrition, 57(12), 1562–8. https://doi.org/10.1038/sj.ejcn.1601725

Mosites, E., S. M. Thumbi, E. Otiang, T. F. McElwain, M. K. Njenga, P. M. Rabinowitz, A. Rowhani-Rahbar, M. L. Neuhouser, S. May, G. H. Palmer, and J. L. Walson. 2016. "Relations between Household Livestock Ownership, Livestock Disease, and Young Child Growth." Journal of Nutrition 146 (5): 1118–1124.

Murphy, S., and L. Allen. 2003. "Nutritional Importance of Animal Source Foods." Journal of Nutrition 133: 3932s–3935s.

Mutero, C. M., C. Kabutha, V. Kimani, L. Kabuage, G. Gitau, J. Ssennyonga, J. Githure, L. Muthami, A. Kaida, L. Musyoka, E. Kiarie, and M. Oganda. 2004. "A Transdisciplinary Perspective on the Links between Malaria and Agroecosystems in Kenya." Acta Tropica 89 (2): 171–186.

Nasreen , S., S. U. Khan, S. P. Luby, E. S. Gurley, J. Abedin, R. U. Zaman, B. M. Sohel, M. Rahman, K. Hancock, M. Z. Levine, V. Veguilla, D. Wang, C. Holiday, E. Gillis, K. Sturm-Ramirez, J. Bresee, M. Rahman, T. M. Uyeki, J. M. Katz, and E. Azziz-Baumgartner. 2015. "Highly Pathogenic Avian Influenza A(H5N1) Virus Infection among Workers at Live Bird Markets, Bangladesh, 2009–2010." Emerging Infectious Disease Journal 21 (4): 629.

Nemeth, E., Rivera, S., Gabayan, V., Keller, C., Taudorf, S., Pedersen, B. K., & Ganz, T. (2004). IL-6 mediates hypoferremia of inflammation by inducing the synthesis of the iron regulatory hormone hepcidin. Journal of Clinical Investigation, 113(9), 1271–1276. https://doi.org/10.1172/JCI20945

Neumann, C., D. M. Harris, and L. M. Rogers. 2002. "Contribution of Animal Source Foods in Improving Diet Quality and Function in Children in the Developing World." Nutrition Research 22 (1–2): 193–220.

Ngure, F. M., B. M. Reid, J. H. Humphrey, M. N. Mbuya, G. Pelto, and R. J. Stoltzfus. 2014. “Water, Sanitation, and Hygiene (WASH), Environmental Enteropathy, Nutrition, and Early Child Development: Making the Links.” Annals of the New York Academy of Sciences 1308: 118–128.

Ngure, F. M., Humphrey, J. H., Mbuya, M. N. N., Majo, F., Mutasa, K., Govha, M., … Stoltzfus, R. J. (2013). Formative research on hygiene behaviors and geophagy among infants and young children and implications of exposure to fecal bacteria. American Journal of Tropical Medicine and Hygiene, 89(4), 709–716. https://doi.org/10.4269/ajtmh.12-0568

Ngure, F. M., J. H. Humphrey, M. N. Mbuya, F. Majo, K. Mutasa, M. Govha, E. Mazarura, B. Chasekwa, A. J. Prendergast, V. Curtis, K. J. Boor, and R. J. Stoltzfus. 2013. “Formative Research on Hygiene Behaviors and Geophagy among Infants and Young Children and Implications of Exposure to Faecal Bacteria.” American Journal of Tropical Medicine and Hygiene 89 (4): 709–716.

Northrop, A., Behrens, H., Lunn, P. G., & Hanlon, W. (1987). Factors affecting the integrity of Gambian children1 ’ 2 of the intestinal mucosa.

Olney, D. K., A. Pedehombga, M. T. Ruel, and A. Dillon. 2015. “A 2-Year Integrated Agriculture and Nutrition and Health Behavior Change Communication Program Targeted to Women in Burkina Faso Reduces Anemia, Wasting, and Diarrhea in Children 3–12.9 Months of Age at Baseline: A Cluster-Randomized Controlled Trial.” Journal of Nutrition 145 (6): 1317–1325.

Patil, S. R., Arnold, B. F., Salvatore, A. L., Briceno, B., Ganguly, S., Colford, J. M., & Gertler, P. J. (2015). The effect of India’s total sanitation campaign on defecation behaviors and child health in rural Madhya Pradesh: A cluster randomized controlled trial. PLoS Medicine, 11(8). https://doi.org/10.1371/journal.pmed.1001709

Pickering, A. J., & Davis, J. (n.d.). Freshwater availability and water fetching distance affect child health in Sub-Saharan Africa, (510), 1–10.

Pickering, A. J., Djebbari, H., Lopez, C., Coulibaly, M., & Alzua, M. L. (2015). Effect of a community-led sanitation intervention on child diarrhoea and child growth in rural Mali: A cluster-randomised controlled trial. The Lancet Global Health, 3(11), e701–e711. https://doi.org/10.1016/S2214-109X(15)00144-8

Pickering, A. J., Julian, T. R., Marks, S. J., Mattioli, M. C., Boehm, A. B., Schwab, K. J., & Davis, J. (2012). Fecal Contamination and Diarrheal Pathogens on Surfaces and in Soils among Tanzanian Households with and without Improved Sanitation. Environmental Science & Technology, 46(11), 5736–5743. https://doi.org/10.1021/es300022c

Pinstrup-Andersen, P. 2012. Food Systems and Human Health and Nutrition: An Economic Policy Perspective with a Focus on Africa. Stanford, CA, US: Center for Food Security and the Environment, Stanford University.

Popkin, B. M., and C. Hawkes. 2016. “Sweetening of the Global Diet, Particularly Beverages: Patterns, Trends, and Policy Responses.” Lancet Diabetes and Endocrinology 4 (2): 174–186.

Prendergast, A. J., Humphrey, J. H., Mutasa, K., Majo, F. D., Rukobo, S., Govha, M., … Stoltzfus, R. J. (2015). Assessment of environmental enteric dysfunction in the SHINE Trial: Methods and challenges. Clinical Infectious Diseases, 61(Suppl 7), S726–S732. https://doi.org/10.1093/cid/civ848

Prendergast, A., and P. Kelly. 2012. “Enteropathies in the Developing World: Neglected Effects on Global Health.” American Journal of Tropical Medicine and Hygiene 86 (5): 756–763.

Prentice, A. M., Doherty, C. P., Abrams, S. A., Cox, S. E., Atkinson, S. H., Verhoef, H., … Drakesmith, H. (2012). Hepcidin is the major predictor of erythrocyte iron incorporation in anemic African children. Blood, 119(8), 1922–1928. https://doi.org/10.1182/blood-2011-11-391219

Prüss-Ustün, A. & Corvalan, C. (2006). Preventing disease through healthy environments: Towards an estimate of the environmental burden of disease. Geneva: World Health Organization.

Rah, J. H., Cronin, A. A., Badgaiyan, B., Aguayo, V. M., Coates, S., & Ahmed, S. (2015). Household sanitation and personal hygiene practices are associated with child stunting in rural India : a cross-sectional analysis of surveys. https://doi.org/10.1136/bmjopen-2014-005180

Richard, S. A., Black, R. E., Gilman, R. H., Guerrant, R. L., Kang, G., Lanata, C. F., … Checkley, W. (2013). Diarrhea in early childhood: Short-Term association with weight and long-Term association with length. American Journal of Epidemiology, 178(7), 1129–1138. https://doi.org/10.1093/aje/kwt094

Routray, P., W. P. Schmidt, S. Boisson, T. Clasen, and M. W. Jenkins. 2015. “Socio-cultural and Behavioural Factors Constraining Latrine Adoption in Rural Coastal Odisha: An Exploratory Qualitative Study.” BMC Public Health 15: 880.

Ruel , M., J. Harris, and K. Cunningham. 2013. “Diet Quality in Developing Countries.” In Diet Quality: An Evidence-Based Approach. Vol. 2, edited by V. R. Preedy, 239–261. New York: Springer.

Ruel, M. T., & Alderman, H. (2013). Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition? Lancet, 382(9891), 536–51. https://doi.org/10.1016/S0140-6736(13)60843-0

Save the Children/Ethiopia and Manoff Group. 2014. Water, Hygiene and Sanitation (WASH) in Rural Households in Amhara, Oromia, SNNP and Tigray: A Report on the Findings and Recommendations of a Multi-method Qualitative Research Study for Social and Behavior Change Communication Programming in Ethiopia. Addis Ababa, Ethiopia: Save the Children/Ethiopia and Manoff Group.

Schlaudecker, E. P., Steinhoff, M. C., & Moore, S. R. (2011). Interactions of diarrhea, pneumonia, and malnutrition in childhood: recent evidence from developing countries. Current Opinion in Infectious Diseases, 24(5). Retrieved from http://journals.lww.com/co-infectiousdiseases/Fulltext/2011/10000/Interactions_of_diarrhea,_pneumonia,_and.16.aspx

Schmidt, W.-P., Cairncross, S., Barreto, M. L., Clasen, T., & Genser, B. (2009). Recent diarrhoeal illness and risk of lower respiratory infections in children under the age of 5 years. International Journal of Epidemiology, 38(3), 766–72. https://doi.org/10.1093/ije/dyp159

Schriewer, A., M. Odagiri, S. Wuertz, P. R. Misra, P. Panigrahi, T. Clasen, and M. W. Jenkins. 2015. “Human and Animal Fecal Contamination of Community Water Sources, Stored Drinking Water and Hands in Rural India Measured with Validated Microbial Source Tracking Assays.” American Journal of Tropical Medicine and Hygiene 93 (3): 509–516.

Simango, C. (2006). Prevalence of Clostridium difficile in the environment in a rural community in Zimbabwe. Transactions of the Royal Society of Tropical Medicine and Hygiene, 100(12), 1146–50. https://doi.org/10.1016/j.trstmh.2006.01.009

Spears, D. (2013). How Much International Variation in Child Height Can Sanitation Explain ? Policy Research Working Paper, Water, Sanitation Program, 6351(February).

Spears, D., A. Ghosh, and O. Cumming. 2013. “Open Defecation and Childhood Stunting in India: An Ecological Analysis of New Data from 112 Districts.” PLoS ONE 8 (9): e73784.

Stephenson, L. S., Latham, M. C., & Ottesen, E. A. (2000). Malnutrition and parasitic helminth infections. Parasitology, 121(S1), S23. https://doi.org/10.1017/S0031182000006491

Stoltzfus, R. J., Mullany, L., & Black, R. E. (2002). Iron deficiency and global burden of disease. In Comparative Quantification of Health Risks: The Global and Regional Burden of Disease due to 25 Selected Major Risk Factors. (2004;1). Geneva: World Health Organization.

Stoltzfus, R., Albonico, M., Chwaya, H., Savioli, L., Tielsch, J., Schulze, K., & Yip, R. (1996). HemoQuant determination of hookworm-related blood loss and its role in iron deficiency in African children. American Journal of Tropical Medicine and Hygiene, 55, 399–404.

Stoltzfus, R., Chwaya, H., Montresor, A., Tielsch, J., Jape, J., Albonico, M., & Savioli, L. (2004). Low dose daily iron supplementation improves iron status and appetite but not anemia, whereas quarterly anthelminthic treatment improves growth, appetite and anemia in Zanzibari preschool children. Journal of Nutrition, 134, 348–356.

Strunz, E. C., Addiss, D. G., Stocks, M. E., Ogden, S., Utzinger, J., & Freeman, M. C. (2014). Water, Sanitation, Hygiene, and Soil-Transmitted Helminth Infection: A Systematic Review and Meta-Analysis. PLoS Medicine, 11(3). https://doi.org/10.1371/journal.pmed.1001620

Thumbi, S. M., Njenga, M. K., Marsh, T. L., Noh, S., Otiang, E., Munyua, P., … Palmer, G. H. (2015). Linking Human Health and Livestock Health : A " One-Health " Platform for Integrated Analysis of Human Health , Livestock Health , and Economic Welfare in Livestock Dependent Communities, (February 2013), 1–18. https://doi.org/10.1371/journal.pone.0120761

Unger, H. W., P. Ashorn, J. E. Cates, K. G. Dewey, and S. J. Rogerson. 2016. "Undernutrition and Malaria in Pregnancy: A Dangerous Dyad?" BMC Medicine 14 (1): 142.

van den Bold, Mara and Quisumbing, Agnes R. and Gillespie, Stuart, Women's Empowerment and Nutrition: An Evidence Review (September 1, 2013). IFPRI Discussion Paper 01294.

van Stuijvenberg, M., Kvalsvig, J., Faber, M., Kruger, M., Kenoyer, D., & Benade, A. (1999). Effect of iron-, iodine-, and B-carotene-fortified biscuits on the micronutrient status of primary school children: a randomized controlled trial. The American Journal of Clinical Nutrition, 69(3), 497–503.

Walker, C. L. ., Perin, J., Katz, J., Tielsch, J. M., & Black, R. E. (2013). Diarrhea as a risk factor for acute lower respiratory tract infections among young children in low income settings. Journal of Global Health, 3(1), 10402. https://doi.org/10.7189/jogh.03.010402

Webb, P. 2013. Impact Pathways from Agricultural Research to Improved Nutrition and Health: Literature Analysis and Research Priorities. Rome: Food and Agriculture Organization of the United Nations.

Weiss, G., & Goodnough, L. T. (2005). Anemia of Chronic Disease. New England Journal of Medicine, 352(10), 1011–1023. https://doi.org/10.1056/NEJMra041809

Welch, V. A., E. Ghogomu, A. Hossain, S. Awasthi, Z. A. Bhutta, C. Cumberbatch, R. Fletcher, J. McGowan, S. Krishnaratne, E. Kristjansson, S. Sohani, S. Suresh, P. Tugwell, H. White, and G. A. Wells. 2017. "Mass Deworming to Improve Developmental Health and Wellbeing of Children in Low-Income and Middle-Income Countries: A Systematic Review and Network Meta-analysis." Lancet Global Health 5 (1): e40–e50.

Zambrano, L. D., Levy, K., Menezes, N. P., & Freeman, M. C. (2014). Human diarrhea infections associated with domestic animal husbandry: A systematic review and meta-analysis. Transactions of the Royal Society of Tropical Medicine and Hygiene, 108(6), 313–325. https://doi.org/10.1093/trstmh/tru056

Ziegelbauer, K., Speich, B., M??usezahl, D., Bos, R., Keiser, J., & Utzinger, J. (2012). Effect of sanitation on soil-transmitted helminth infection: Systematic review and meta-analysis. PLoS Medicine, 9(1). https://doi.org/10.1371/journal.pmed.100116

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