Evaluation of a community-led total sanitation intervention in a rural area of the Southern Nations, Nationalities, and Peoples' Region, Ethiopia

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Declaration

I, Seungman Cha, confirm that the work presented in this thesis is my own.

Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Seungman Cha

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Abstract

Sanitation has historically been regarded as an effective tool to interrupt the transmission of faecal pathogens. Until 2016, however, there has been just one trial investigating effect of a community-led total sanitation (CLTS) intervention on child diarrhea. Most cost-benefit analyses of sanitation interventions have been either theoretical estimations or based on observational studies. The thesis aims to assess the effect of a CLTS intervention on child diarrhea, explore the existence of a sanitation externality, and investigate its economic efficiency. The trial was conducted in a rural area of Ethiopia from 2015 to 2017, enrolling 906 children in 24 intervention and 24 control clusters.

There were decreases in both the incidence and longitudinal prevalence of child diarrhoea. After adjusting for clustering and stratification, the incidence ratio and longitudinal prevalence ratio were 0.66 (95% confidence interval [CI], 0.45–0.97; p=0.03) and 0.70 (95% CI, 0.52–0.95; p=0.02), respectively. There was, however, inconclusive evidence regarding the effect on the 7-day period prevalence at 10 months (relative risk=0.75; 95% CI, 0.35–1.60; p=0.45) post-triggering. Higher-quality latrines were associated with a reduction in child diarrhoea compared to those not meeting these criteria (Odds Ratio [OR]=0.46; 95% CI, 0.27–0.81; p=0.006). Children living in households with an unimproved latrine, those in high-coverage villages had a lower risk of diarrhoea than those in low-coverage villages (adjusted OR=0.55; 95% CI, 0.35–0.86, p=0.008). The base case benefit–cost ratio was determined to be 3.7 (95% Credible Interval, 1.9–5.4), and the net present value was calculated to be Int'l$1,193,786 (95% Credible Interval, 406,017–1,977,960).

This CLTS intervention has the potential to reduce child diarrroea in a cost-effective way. There was evidence for substantial sanitation externalities. However, the quality and design of latrines should receive more attention in sanitation interventions, as low-quality latrines offered little protection.

Acknowledgements

I would like to express my sincere gratitude to my supervisors, Wolf-Peter Schmidt and Ian Ross for their continuous guidance to explore health and economic effect of a community-led total sanitation. Especially, I thank Val Curtis for her supervision and patience when I was stuck in my Organization and Policy Analysis (OPA) project. I feel very fortunate to have benefited from the immense knowledge, motivation, and patience from my supervisors.

Thanks also go to my colleagues who have made tremendous efforts to improve sanitation in Gurage zone, SNNPR state in Ethiopa: Dawit Belew Bizuneh; Girma Negussie Habteyes; Tadesse Abera; Sunghoon Jung; Hyunjin Kwon and all other project team members. I extend my appreciation to the community people, the CLTS promoters, Health Extension Workers, and District Health Directors of Enemore Ena Ener and Cheha districts. I am also grateful to Soonyoung Choi, the supervisor of host organization (World Vision Korea) of my Organization and Policy Analysis (OPA) project, and also to all the colleagues of World Vision who participated in the in-depth interview or focus group discussion.

Thank you, my wife (Yan Jin) and my son (Dosol) for your love, prayers and sacrifices. You have always kept me going until I could see the end of the long tunnel.

Dedication

My interaction with Jeroen Ensink, then my supervisor, was short but strong and impressive. In a few minutes after I met him at the lobby of the school for the first time in September 2015, he expressed his hope that I would be able to complete the course in 3 years. Although I could not make it, I always think of his encouraging comments. One day, he presented two football tickets to me, suggesting that I leave the library and spend a wonderful time with my wife during weekend. Then my wife and I searched a gift for his baby to be born soon. We bought a white horse toy with beautiful wings. It was too late when we visited his office with the gift. I always remember his optimism, encouragement and humbling works.

This thesis is dedicated to the memory of Dr. Jeroen Ensink.

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List of Abbreviations

AIC	Akaike information criterion
BCR	Benefit-cost ratio
CLTS	Community-Led Total Sanitation
CLTSH	Community Led Total Sanitation and Hygiene
CBA	Cost-benefit analysis
DALY	Disability-adjusted life year
HEW	Health extension workers
ISRCT	International Standard Randomized Controlled Trial
IOR	Interval odds ratios
JMP	Joint Monitoring Program
KOICA	Korea International Cooperation Agency
MOR	Median odds ratio
MDGs	Millennium Development Goals
NRERC	National Research Ethics Review Committee
PCV	Proportional change in community variance
SDGs	Sustainable Development Goals
SNNPR	the Southern Nations, Nationalities, and Peoples' Region
VSL	Value of a statistical life
WASH	Water, Sanitation, and Hygiene

CHAPTER 1. Introduction

Introduction To The Thesis

In 2019, diarrheal disease was the cause of death for 1.5 million people, 0.48 million of whom were under-five children in 2019 (GBD, 2020; Perin et al, 2022). It is estimated that 60% of these diarrhea-specific deaths can be attributed to inadequate water, sanitation, and hygiene practices (WASH) (WHO, 2023). In a 2007 poll conducted by the *British Medical Journal*, sanitation was chosen as the most significant medical advancement since 1840 (Ferriman et al., 2007). According to a recent review by Bauza et al. (2023), there have been 12 randomized control trials conducted to evaluate the effects of community-based sanitation interventions on child diarrhea, excluding the trial discussed in this thesis. Surprisingly, 10 of these trials found no effect (Bauza et al., 2023). This unexpected outcome has been discussed extensively (e.g. Cumming and Curtis, 2018; Cumming et al., 2019).

Meanwhile, a recent review on sanitation interventions underscored the need for research into costs and benefits of these interventions, the results chain from sanitation interventions to health outcomes, and sanitation externalities (Radin et al., 2020). The review highlighted that: 1) few studies have investigated the details of the results chain or the theory of change from sanitation interventions to health outcomes; 2) no trials collected empirical values for the parameters needed for economic evaluations; and 3) current studies on sanitation externalities primarily depend on hypothetical basis rather than empirical evidence.

To address some of these knowledge gaps, a cluster randomized control trial was conducted in a rural area of the Southern Nations, Nationalities, and Peoples' Region (SNNPR), Ethiopia.

DrPH Research Context

Prior to planning our trial, systematic reviews and meta-analyses had underscored the needs for research evaluating the effect of sanitation on diarrhea using more robust designs (Clasen et al., 2006; Fewtrell et al., 2005). We began designing our trial in Ethiopia in 2014. At that time, two studies had been published on the effect of sanitation on child diarrhea in India (Clasen et al., 2014; Patil et al., 2014), both of which found no significant reduction in diarrhea. We hypothesized that the lack of effect might be due to low coverage or poor structure of the latrines used in their trials. Consequently, we developed stricter criteria for defining an improved latrine than those used in the Joint Monitoring Programme by the World Health Organization and the United Nation's Children's Fund.

Simultaneously, we emphasized the importance of collecting data related to intermediary outcomes (e.g., latrine coverage, latrine structure, latrine use, number of flies inside a latrine, presence of faeces on the latrine floor, number and presence of faeces inside and outside the household compound). We believed this would help us understand the chain of results from the intervention to child diarrhea, providing clues about the effectiveness of sanitation interventions. We also stressed the need for more objective data collection. We tried to make direct observation including latrine quality and latrine use instead of relying solely on participants' responses to questions. In addition, we distributed diarrhea calendar so that caregivers could record existence of diarrhea episode of registered child on a daily basis.

Research Aims and Objectives

The aim of this research was to evaluate the health and economic effects of a community-led total sanitation (CLTS) intervention implemented in rural areas of Ethiopia.

According to the latest review (Bauza et al., 2023), 12 trials of community-based sanitation interventions were conducted to assess their effect on diarrhea, including one trial of a CLTS intervention in Mali (Pickering et al., 2015). Out of the 13 community-based trials, only two found a significant effect. Despite the rise of CLTS, studies assessing its impact on sanitation coverage or child diarrhea are still scarce. Generalizing the effect of a single CLTS intervention to other countries or contexts is challenging. Additionally, many of the existing trials did not thoroughly examine the results chain from interventions to diarrhea, primarily focusing on exploring effects on diarrhea and/or nutritional outcomes.

Therefore, the first specific objective of this thesis was to investigate the effect of a CLTS intervention on child diarrhea, while also examining the chain of results with a focus on intermediate outcomes.

Many of the existing trials used the UNICEF/WHO definition of an improved latrine ("JMP-improved"). A pit latrine with a slab has been considered an improved latrine by UNICEF since 2008. However, some have highlighted the importance of hygienic latrines beyond the "improved sanitation" defined by the Millennium Development Goals (Nakagiri et al., 2015; Nakakiri et al., 2016). Against this backdrop, a number of countries in sub-Saharan Africa have adopted policies for sanitation improvements, but there was little emphasis on the minimum standard of pit latrines required for disrupting the transmission of fecal-oral pathogens, with the exception of a few countries (Bongarzt et al., 2016). According to a review of the performance of pit latrines, despite their widespread application and use across the globe, the relationship between latrine type or design and performance on health outcomes has not been thoroughly assessed (Nakagiri et al., 2016).

For this reason, I aimed to compare the performance of latrines on diarrhea by latrine type, which is the second specific objective of the thesis.

Herd protection refers to the concept that an intervention against an infectious disease can indirectly protect people who do not receive the intervention. If there is a herd protective effect of an intervention against infectious diseases that are transmitted from person to person or when humans are important reservoirs of the pathogen, the intervention can lower the risk of infection among those who do not receive it. The herd protective effect of sanitation has been hypothesized, but empirical evidence is scarce. Therefore, I aimed to explore the existence of a herd protective effect of sanitation, which was the fourth specific objective of the thesis.

There has been an increasing need for economic evaluations of sanitation interventions. Most existing cost-benefit or cost-effectiveness analyses of sanitation interventions have used parameter values generated from hypothetical reasoning or meta-analysis results. Most existing trials have not included an economic evaluation. According to a recent review of the knowledge base for sanitation interventions, most cost-benefit analyses (CBAs) were identified as presenting global-level and/or ex-ante analyses, relying heavily on assumptions for parameter values (Radin et al., 2020). The authors suggested that more ex-post CBA studies using empirical data from intervention settings to inform model parameters are required. Other studies have also emphasized that costs and benefits can be highly context-specific, arguing for more empirical studies (Hutton & Chase, 2016; Hutton, 2013; Radin et al., 2020). Therefore, I aimed to conduct a cost-benefit analysis of a CLTS intervention, primarily relying on an empirical dataset collected alongside the trial.

The specific objectives of this study were to:

1) assess whether a CLTS intervention reduced child diarrhea;

2) analyse the performance of pit latrines by type and explore existence of herd protective effect of sanitation intervention;

3) estimate the costs and benefits of the CLTS intervention.

Thesis Components

This thesis applies a research paper style format and comprises seven chapters, including this one, as summarised below.

In addition to the seven chapters regarding the health and economic evaluation of a CLTS intervention, there is another part of the thesis, an Organization and/or Policy Analysis report.

Chapter 1 is an introduction to the DrPH thesis. The chapter covers the context for the DrPH research as well as the aim and objectives of the research.

Chapter 2 presents a literature review that explores the effects of sanitation interventions on child diarrhea and intermediate outcomes as well as the cost-benefit and cost-effectiveness of these interventions. A systematic review and meta analysis was published in January 2023 by Bauza et al., which examined the effects of on sanitation interventions on diarrhea in both adults and children. In addition to this recent publication, there are over 160 review papers on water, sanitation, and hygiene. However, none of these reviews, including the most recent one, comprehensively address the results chain from the intervention to the health outcome, specifically diarrhea. Therefore, the review concentrates on the influence of sanitation interventions on intermediate outcomes, aiming to elucidate potential reasons for the presence or absence of its effect on child diarrhea. This approach is intended to prevent any overlap between my review and the latest systematic review and meta-analysis.

Chapter 3 presents the study protocol of the trial undertaken in Gurage zone, SNNPR state, Ethiopia.

This study protocol provides a comprehensive description of all pertinent details. This includes the study design, study settings, sampling and sample size, intervention and procedures, randomization and masking, measurement methods, and operational definition of improved latrines. Additionally, the methods of statistical analysis, as well as the background and implications of this trial, are explained.

The protocol was drafted by Seungman Cha as Principal Investigator and reviewed by other authors including the first author, Sunghoon Jung, who as the trial project manager.

This study protocol was published in ***Trials*** in April 2016.

Chapter 4 presents the health effects of the CLTS intervention on child diarrhea.

This study reports the effects of CLTS on child diarrhea, both in terms of period prevalence and longitudinal prevalence. Additionally, the study describes the intervention's effects on intermediate outcomes, including the presence and number of flies around the pit hole, faeces on the latrine floor, faeces inside and outside of the household compound, and latrine access and use.

Seungman Cha analysed the data and drafted the manuscript under the guidance of Wolf-Peter Schmidt. Sunghoon Jung, Tadesse Abera and Dawit Belew Bizuneh contributed to project administration. Wolf-Peter Schmidt contributed to the theoretical and practical considerations of the analysis and interpretation.

This study was published in ***American Journal of Tropical Medicine and Hygiene*** in June 2021.

Chapter 5 provides an overview of the performance of various types of pit latrines, as well as the results of an analysis of the herd protection of these latrines.

This study examines whether the risk of diarrhea in children under-five differs between those residing in households with unimproved latrines and those with JMP-improved latrines, as defined by the Joint Monitoring Programme (JMP). It also compares the odds between those living with a JMP-improved latrine and those with a study-improved latrine as operationally defined by this study. Furthermore, it investigates the presence of sanitation externality.

Seungman Cha and Sunghoon Jung conceived and designed the study; Sunghoon Jung, Tadesse Abera and Dawit Belew Bizuneh coordinated the data collection; Seungman Cha developed the data analysis plan; Sunghoon Jung, Tadesse Abera and Dawit Belew Bizuneh contributed to project administration; Seungman Cha and Yan Jin analyzed the data and interpreted the results; Tadesse Abera and Ermias Tadesse contributed to data curation; Seungman Cha wrote the first draft; Wolf-Peter Schmidt and Ian Ross contributed to the theoretical and practical considerations of the analysis and interpretation.

This study is under review by the ***Global Health: Science and Practice*** as of 14 January 2024.

Chapter 6 presents the economic efficiency of the community-led total sanitation intervention.

In this study, the costs and benefits of CLTS are analysed.

Seungman Cha, Sunghoon Jung, and Jieun Seong conceptualized the study. Seungman Cha, Jieun Seong, Dawit Belew Bizuneh and Tadesse Abera implemented the trial. Seungman Cha conducted the statistical analysis and wrote the draft of the manuscript under the guidance of Ian Ross.

This study was published in ***International Journal of Environmental Research and Public Health*** in July 2020.

Chapter 7 presents the key findings of the thesis and recommendations for further research or sanitation interventions. In addition, strengths and limitations of the research are discussed.

Intellectual Ownership, Funding, and Ethical Approval

I led the design, implementation, data collection, and analysis of this thesis. Most other research elements were also led by me, with support and advice from my supervisors, advisory committee, and upgrading examiners. The Korea International Cooperation Agency generously funded the entire cost of project implementation and data collection. No additional support was provided for the research.

All research activities presented in this thesis received the necessary ethical approvals from the LSHTM Ethics Review Committee and from Ethics Review Committees in Ethiopia where the research was carried out. The ethical approvals for research activities are detailed below and approval certificates can be found in Appendix:

① Chapter 3 (**Study protocol of the trial**) – Ethical approval was granted by the Ministry of Science and Technology, Federal Democratic Republic of Ethiopia. (reference number: NRERC 3.10/032/2015).

② Chapter 4-6 (**Effects of CLTS on child diarrhea; Performance of pit latrines and herd protection; Benefits and costs of a CLTS**) – Ethical approval granted from LSHTM (reference number: 16260) and the Ministry of Science and Technology, Federal Democratic Republic of Ethiopia. (reference number: NRERC 3.10/032/2015).

CHAPTER 2. Literature Review

2.1. Effect of sanitation interventions on child diarrhea and intermediate outcomes

2.1.1 Background

Diarrhea was responsible for 3.2% of disability-adjusted life-years (DALYs) across all ages in 2019, making it the fourth leading cause of death in children under 5 (GBD 2017 DALYs and HALE Collaborators, 2018; Troeger et al., 2018). The pathogens of diarrhea are found in human excreta. Therefore, it is crucial to contain human excreta to prevent those pathogens from being introduced into the environment (Carr et al., 2001). Pathogens in the environment can be transmitted in various ways, including indirect routes such as contaminated food, water, fomites, and insect vectors, or through direct person-to-person spread (Carr et al., 2001; Wagner, 1958). As such, the first barrier to interrupt the transmission of these pathogens is the proper management, safe disposal, and handling of excreta (Carr et al., 2001). However, of an estimated 1.6 million diarrhea-specific deaths in 2017, 774,000 deaths were reported to be due to unsafe sanitation (GBD 2017 Risk Factor Collaborators, 2018; GBD 2017 Causes of Deaths Collaborators, 2018). In another study, inadequate sanitation was estimated to cause 396,000 deaths, which was approximately 29% of all diarrheal deaths in 2016 (Prüss-Ustün et al., 2019).

The Sustainable Development Goals (SDGs) aim to ensure universal access to sanitation by 2030 (United Nations, 2015). However, as of 2020, it is estimated that 545 million individuals were still utilizing unimproved sanitation facilities, and approximately 419 million people continued to defecate in the open (WHO/UNICEF, 2023).

Until 2014, when I designed this trial, there had been few robust studies accompanying sanitation improvements. Despite numerous governments and non-governmental organizations incorporating sanitation enhancements into their policies, there was a scarcity of solid evidence regarding the effect of sanitation interventions, including CLTS, on health outcomes.

Consequently, I conducted a randomized controlled trial (RCT) in rural Ethiopia to evaluate the effect of a sanitation intervention on child diarrhea.

In recent years, numerous reviews have evaluated the effects of sanitation interventions on health outcomes, as well as latrine coverage and use (Freeman et al., 2017; Garn et al., 2017; Sclar et al., 2016; Venkataramanan et al., 2018; Wolf et al., 2022; Radin et al., 2020). Venkataramanan et al. (2018) examined the effect of CLTS interventions specifically on these outcomes, incorporating 14 quantitative evaluation studies. The evaluation reported decreases in open defecation. However, the quality of evidence from the studies included in these reviews, with the exception of the most recent one (Bauza et al., 2023), was rated as low or very low. The most recent review, published in January 2023 by Bauza et al. (2023), performed a separate meta-analysis for RCTs.

Out of the 13 RCTs of community-based sanitation interventions reviewed, 11 did not demonstrate a significant effect on the period prevalence of child diarrhea. This leaves substantial gaps in our understanding of the results chain or theory of change from sanitation interventions to childhood diarrhea.

This chapter reviews the effects of sanitation interventions, including CLTS, on child diarrhea and intermediate outcomes, with the aim of updating the existing body of evidence. There is a room for more exploration into the probable reasons for the lack of effect in recent sanitation trials since recent reviews have not thoroughly investigated the results chain from intervention to health outcomes.

The focus is solely RCTs of community-based sanitation interventions and their effects on child diarrhea. Randomized controlled trials (RCTs) are the acknowledged standard in evaluating effectiveness and are recognized as best method for generating evidence (Smith JR, 2024). The even distribution of confounding factors between intervention and control groups can be ensured by the random allocation of study subjects, which minimizes bias in assessing the effects of an intervention.

While the most recent review (Bauza et al., 2023) did conduct a separate meta-analysis of RCTs, its focus was on analyzing the effects of sanitation intervention. In contrast, this chapter concentrates on investigating potential reasons for the presence or absence of the effect of sanitation intervention on child diarrhea, delving into the results chain from intervention to the health outcome (diarrhea). Specifically, I re-reviewed studies included by Bauza et al. (2023) but with a focus on data for intermediary outcomes along the results chain rather than the diarrhoea outcome.

2.1.2. Method

Study eligibility and search strategy

I reviewed only RCTs that evaluated the effect of community-based sanitation interventions on child diarrhea. Institution-based interventions were excluded. The RCTs I selected were the ones included in the most recent review, published in January 2023 (Bauza et al., 2023).

The search strategy in the latest review is described in Table 1.

In the latest review, the search period was until February 2022. I extended the search period to 30 June 2024 following the search strategy employed by Bauza et al. The database was restricted to the Cochrane Central Register of Controlled Trials (CENTRAL) published in the Cochrane Library; and PubMed. I was unable to conduct a search in LILACS (Latin American and Caribbean Health Science Information database) or Chinese language databases available under the China National Knowledge Infrastructure (CNKI-CAJ), or other resources, which is one of the limitations of the thesis. I could not find any other RCTs investigating the effect of community-based interventions on child diarrhea.

Table 1. Search strategy adopted by the latest review (Bauza et al., 2023)

Category	Contents
Database	Cochrane Infectious Diseases Group Specialized Register; Cochrane Central Register of Controlled Trials (CENTRAL) published in the Cochrane Library; MEDLINE; Embase; and LILACS (Latin American and Caribbean Health Science Information database) Chinese language databases available under the China National Knowledge Infrastructure (CNKI-CAJ) the metaRegister of Controlled Trials (mRCT)
Other resources	Conference proceedings: International Water Association and the Water, Engineering and Development Centre, Loughborough University, UK. Researchers and organizations: contacting individual researchers and the following organizations: the Water, Sanitation and Health Programme of the WHO; World Bank Water and Sanitation Program; UNICEF Water, Sanitation and Hygiene; Environmental Health Project; IRC International Water and Sanitation Centre;

	Foodborne and Diarrheal Diseases Branch, Division of Bacterial and Mycotic Diseases, Centers for Disease Control and Prevention (CDC); US Agency for International Development (USAID); and the UK Department for International Development (DFID) Checking reference lists: checked the reference lists of all studies identified by the above methods
Period for search	~16 February 2022
Primary outcomes	Diarrhoea amongst individuals, whether or not confirmed by microbiological or clinical examination
Type of interventions	① Providing access to any sanitation facility ② Sanitation facility improvement ③ Behaviour change messaging only

Target populations and primary outcomes

The target populations comprised children under 5 years old, specifically those aged up to to 59 months at the time of enrolment. The primary outcomes focused on instances of child diarrhea such as period prevalence. Diarrhea was defined, according to the WHO, as the occurrence of three or more loose stools within 24-hour period (WHO, 2023).

Exposure

In this review, I focus solely on experimental studies, with the exposures being sanitation interventions. These interventions could involve the provision of sanitation facilities, improvements to existing sanitation facilities, the promotion of behaviour change such as CLTS, or a combination of these components. All behaviour change interventions were included, irrespective of the approach taken—that is, studies were analyzed regardless of whether or not they strictly adhered to the two principles of CLTS, namely ‘no financial/material subsidy’ and ‘no pre-specification of latrine design’.

Bauza et al. (2023) classified sanitation interventions into three distinct categories. The first category encompasses interventions that provide individuals with access to a sanitation facility, either through construction or subsidization of these facilities. This category is referred to as providing access to a sanitation facility. Bauza et al. (2023) categorized interventions in the category of providing access to any sanitation facility if they were conducted in settings where the population relied primarily on open defecation. The second category, termed sanitation facility improvement, includes interventions aimed at enhancing existing sanitation facilities, encouraging the building of new facilities, or providing individual household latrines to participants who rely on shared sanitation. Bauza et al. (2023) categorized WASH Benefit studies into this group. The third category, behavior change messaging only, involves interventions that encourage individuals to increase sanitation access or improve the use of existing facilities without any subsidies. In this study, I have categorized the 12 trials included according to these classifications. I did not attempt to investigate the effect size by intervention category, as this was already addressed in the recent review by Bauza et al. (2023).

Analysis

I conducted an in-depth investigation into the 'black box' of the results chain, tracing the path from interventions to diarrhea. This was done to gain a clearer understanding of the potential reasons behind the presence or absence of the effect of sanitation interventions on child diarrhea. For guidance on the results chain, I referred to WHO (2018) and the KOICA WASH project guideline (Kim et al, 2018)[1].

Table 2 outlines the progression from intervention to health outcomes and enumerates the variables I extracted when they were reported in individual studies. The following provides an

[1] This guideline was developed in reference to guidelines, manuals, and reports of many bilateral and multilateral organization and existing literature. The first author of this guideline is an UNICEF WASH specialist.

explanation of the results chain, tracing the path from sanitation interventions to the reduction of child diarrhea incidents.

First, there is the output level. This deals with individual level latrine uptake. At this level, it is worth noting that there are different types of latrines, ranging from simple pit latrines to water-sealed latrines.

Second, there is the intermediate outcome level (latrine quality). Variables include whether the latrine effectively contains human faeces, thereby interrupting the transmission of faecal pathogens; more specifically, whether the latrine minimizes the risk of faecal transmission via flies. It also prevents contact with faeces after defecation through the provision of hand-washing facilities. Furthermore, the latrine prevents contact with faeces in the field, whether on the latrine floor or in the yard (either within or outside the household compound).

Third, there is the intermediate outcome level (collective level). There should be an increase in latrine access and use within the intervention group compared to the control group. Furthermore, this increase is expected to reach a certain threshold level, which is assumed to provide herd protective effect (Fuller and Eisenberg, 2016). Additionally, child faeces should be disposed of appropriately, meaning there should be an increase in the proportion of households that dispose of child faeces appropriately.

"Total" sanitation will be achieved across the community once certain criteria are met. The term "total" sanitation is used in reference to the UNICEF/WHO JMP (2019) report, which indicates that sanitation coverage is lower when considering every individual in a household or community.

The logic outlined in the results chain (Table 2) implies that if all these outputs and intermediate outcomes are achieved, there will be a reduction in prevalence of child diarrhea.

Table 2. Logical framework: Results chain from sanitation interventions to diarrhea reduction

Level	Logical Framework: Result Chain[a]
Output/Activity (type of a latrine) Did the household have an improved toilet?	Simple pit toilet (JMP) pit latrine with slab Pit latrine with slab, floor, wall, roof Pit latrine with slab, and lid Ventilated improved pit latrine A pour-flush Flush toilet with water sealed
Intermediate outcome 1 (performance of a latrine) Did the latrine interrupt transmission of faeces?	Reduction in fly numbers (or fly presence) (Statistically significant reduction in the intervention compared to the control group) Reduction of faeces on latrine floor (Statistically significant reduction in the intervention compared to the control group) Reduction of faeces in household yard (Statistically significant reduction in the intervention compared to the control group) Reduction of child faeces disposal to yard (Statistically significant reduction in the intervention compared to the control group) Hand-washing facilities (regardless the presence of soap and/or water) (Statistically significant increase in the intervention compared to the control group) Reduced fecal contamination on hands (hand-washing facilities with soap and water) (Statistically significant reduction in the intervention compared to the control group)
Intermediate outcome 2 (access, use, collective behavior)	Was the latrine coverage higher in the intervention than the control? (Statistically significantly higher in the intervention than the control) Was the latrine coverage high enough in the intervention? (more than 70%)[b] Were the child faeces disposed appropriately in the intervention compared with control? (Was it significantly higher in the adequate disposal of child faeces in the intervention compared to the control group based on the self-report)? Were the child faeces disposed appropriately in the intervention compared with control? (Was it higher in the adequate disposal of child faeces in the intervention compared to the control group based on direct observation)? Was the percentage of use higher in the intervention than the control? (Was the percentage of use statistically higher in the intervention than the control group based on self-report)? Was the percentage of use higher in the intervention than the control? (Was the percentage of use statistically higher in the intervention than the control group based on the direct observation)? Was the percentage of use high enough in the intervention? (more than 70%)[b] Were the open defecation practices lower in the intervention compared with the control? (Was the open defecation practices statistically lower in the intervention compared with the control based on the self-report?) Were the open defecation practices lower in the intervention compared with the control? (Were the open defecation practices statistically lower in the intervention compared with the control based on direct observation?)

	Was the TOTAL sanitation achieved? (Total sanitation is defined that all the people in a community stop practicing open defecation.)
Outcome	Was there reduction in child diarrhea in the intervention compared to the control? (Was there statistically significant reduction in child diarrhea in the intervention than the control group?)

[a] Criteria of the success is explained in the bracket in the result chain
[b] The 70% coverage is somewhat arbitrary as studies on the threshold of sanitation coverage required for herd protection are scarce. We referred to a study conducted by Andrés et al. (2017) in rural India, which suggested that a substantial herd protective effect on child diarrhea was detected when sanitation coverage reached approximately 75%.
[c] Total sanitation: is operationally defined as none practicing open defecation and everyone using a household latrine in this study.

2.1.3. Results

Description of the selected studies (13 RCTs)

Table 3 lists the 13 trials included in this chapter categorized by the author, year, country and specific type of intervention applied in each trial. Of these 13 trials, eight RCTs were conducted in sub-Saharan African countries, while the remaining five took place in Asia. Out of these five Asian trials, four were conducted in India, with three of them examining the effect of India's Total Sanitation Campaign (TSC).

Table 3. Trials included in this review

Category	Intervention type	Author, year	Country (rural/urban)
Providing participants with access to sanitation facilities, which includes constructing or subsidizing the construction of facilities	India's Total Sanitation Campaign (TSC)	Clasen 2014 Patil 2014 Hammer 2016	India (rural) India (rural) India (rural)
	Improved pit latrine was constructed other WASH components are included (drinking water treatment, hand washing)	Humphrey 2019	Zimbabwe (rural)
Improving participants' existing sanitation facilities	New or upgraded latrines (with a slab and a functional water seal) was provided.	Luby 2018	Bangladesh, rural
	New or upgraded latrines (with a plastic slab) was provided.	Null 2018	Kenya, rural
	Financial subsidy (US$2000) for new or upgrading latrines was provided.	Quattrochi 2021	DR Congo, rural
Behaviour change messaging only, which encourage participants to increase sanitation access or improve the use of existing sanitation facilities without providing or improving facilities or providing subsidies	Total sanitation and sanitation marketing (TSSM)	Cameron 2013	Indonesia, rural
	CLTS	Pickering 2015	Mali, rural
	Total sanitation and sanitation marketing (TSSM)	Briceno 2017	Tanzania, rural
	Community health club programmes were undertaken to promote WASH related health behaviours, including sanitation, drinking water quality, hygiene and other health education.	Sinharoy 2017	Rwanda, rural
	TSC (CLTS style participatory intervention) *They did not articulate "TSC" but it was interpreted as TSC.	Dickinson 2015	India, rural
	CLTS	Cha 2021	Ethiopia, rural

According to the most recent review, 14 RCTs have been published that assessed the effect of sanitation intervention on diarrhea up until 16 February 2022. Of the remaining 14 RCTs, 13 were community-based, and one (Hashi et al., 2017) was school-based and was consequently excluded from this review. Table 4 presents the results of the community-based sanitation intervention RCTs. In all of these trials, diarrhea was ascertained through parental reports on recall periods of 7 days (7 trials), 14 days (5 trials), and/or 2 days (1 trial). Among the 13 community-based sanitation intervention RCTs, two studies (Luby et al., 2018; Hammer and Spears, 2016) found a significant effect on period prevalence of child diarrhea. The trial of CLTS in Ethiopia (Cha et al., 2021) detected significant effect on longitudinal prevalence and incidence of child diarrhea but not on the period prevalence.

Table 4. Overall results of RCTs of community-based sanitation interventions

				Results							
Country	Intervention time	Reference	Intervention	Primary outcome (reported diarrhea)				Latrine coverage after an intervention (percentage point change between before and after)		Latrine use after an intervention (percentage point change between before and after)	
				Period	Intervention	Control	Prevalence ratio/ Prevalence difference (%) (95% CI)	Intervention	Control	Intervention	Control
Indonesia	2008-2011	Cameron et al.(2013)	CLTS + sanitation marketing+advocacy	7 days	2.4%	3.8%	0.64(0.36,1.13)	42.6% (+0.6pp)	43.5% (+1.0pp)		
India	2009-2010	Patil et al. (2014)	TSC	7 days	7.4%	7.7%	-0.003 (-0.019,0.013)[a]	41.4% (+27.8pp)	22.6% (+10.2pp)	27.2% (N/A)	16.7% (N/A)
India	2010-2013	Clasen et al. (2014)	TSC	7 days	8.8%	9.1%	0.97(0.83, 1.12)	63.0% (+54.0pp)	12.0% (+4.0pp)	36.0% (N/A)	9.0% (N/A)
Mali	2011-2013	Pickering et al. (2015)	CLTS	14 days	31.2%	32.0%	0.98(0.82, 1.17)	64.8% (+31.8pp)	34.6% (-0.4pp)	62.3% (96.1%)[b] (N/A)	32.6% (94.3%) (N/A)
India	2005-2006	Dickinson et al (2015)	CLTS style participatory intervention	14 days			0.83(0.61,1.13)	35% (+14.0pp)	15% (+1.0pp)		
India	2004-2005	Hammer & Spears (2016)	TSC	14days			-2.80(-2.83,-2.77)[a]	22.8% (+4.8pp)	14.6% (+4.6pp)		
Tanzania	2009-2011	Briceno et al. (2017)	Sanitation marketing	14 days	14.7%	16.8%	-2.1(-4.6, 0.4)[a]	65.3%	57.1%	64.8%	49.7%

Country	Intervention time	Reference	Intervention	Results: Primary outcome (reported diarrhea)				Latrine coverage after an intervention (percentage point change between before and after)		Latrine use after an intervention (percentage point change between before and after)	
				Period	Intervention	Control	Prevalence ratio/ Prevalence difference (%) (95% CI)	Intervention	Control	Intervention	Control
Rwanda	2013-2015	Sinharoy et al (2017)	Community health clubs	7 days	14%	14%	0.97 (0.81,1.16)	30% (-36pp)	30% (-38pp)		
Bangladesh[c]	2013-2016	Luby et al.(2018)	Material subsidy	7 days	3.5%	5.7%	-2.3(-3.5,-1.1)[a]	97% (+43.0pp)	31% (-23.0pp)	94.1%	40.4%
Kenya[c]	2014-2016	Null et al. (2018)	Material subsidy	7 days	26.5%	27.1%	-0.3(-3.3, 2.6)[a]	78.2% (+70.2pp)	19.6% (+10.6pp)		
Zimbabwe[c]	2012-2015	Humphrey et al (2019)	Providing Ventilated pit latrine to a household	7 days	12%	9%	1.18(0.87,1.61)	99% (+67.0pp)	28% (-1.0pp)	86% (+21.0pp)	22% (+1.0pp)
Ethiopia	2016-2017	Cha et al (2021)	CLTS	7 days	7.7%	9.9%	0.83 (0.60-1.13)	35.0% (+35.0pp)	2.8% (+2.1pp)	36.9% (+11.7pp)	44.8% (+20.1pp)
DR Congo	2019	Quattrochi et al (2021)	Financial subsidy for new or upgrading latrines	14 days	27%	32%	-2 (-11,5)[a]	46% (N/A)	18% (N/A)	N/A	N/A

[a] prevalence difference; [b] The percentage in the brackets is the proportion of latrine use among those who had a latrine, which were indicated in the paper, and I thus re-calculated the percentage using all participants as denominator regardless of their latrine access or ownership.; [c] These trials were based on a household-based or compound-based intervention, not community-based one. Therefore, these percentages do not refer to the community level coverage.; Blank: not described in the report or paper.

Figure 1 shows the results of meta-analysis of 14 RCTs on child diarrhea (Bauza et al., 2023). The meta-analyses in the latest review showed that there was a modest effect of sanitation interventions on child diarrhea (risk ratio=0.87, 95% CI=0.77-0.97).

Study or Subgroup	log[RR]	SE	Weight	Risk Ratio IV, Random, 95% CI
Cluster-RCTs				
Briceno 2017 (1)	-0.0417	0.1441	3.9%	0.96 [0.72 , 1.27]
Cameron 2013 (2)	-0.4512	0.2904	2.2%	0.64 [0.36 , 1.13]
Cha 2021	-0.462	0.4192	1.4%	0.63 [0.28 , 1.43]
Clasen 2014	-0.0336	0.0767	4.7%	0.97 [0.83 , 1.12]
Dickinson 2015	-0.1831	0.1571	3.7%	0.83 [0.61 , 1.13]
Hammer 2016 (2)	-0.8779	0.4335	1.3%	0.42 [0.18 , 0.97]
Hashi 2017	-0.4323	0.0627	4.8%	0.65 [0.57 , 0.73]
Humphrey 2019	0.1664	0.1571	3.7%	1.18 [0.87 , 1.61]
Luby 2018	-0.4943	0.144	3.9%	0.61 [0.46 , 0.81]
Null 2018	-0.0131	0.0568	4.9%	0.99 [0.88 , 1.10]
Patil 2014	-0.0263	0.0966	4.5%	0.97 [0.81 , 1.18]
Pickering 2015	-0.0726	0.103	4.4%	0.93 [0.76 , 1.14]
Quattrochi 2021	-0.081	0.081	4.6%	0.92 [0.79 , 1.08]
Sinharoy 2017 (3)	-0.0305	0.092	4.5%	0.97 [0.81 , 1.16]
Subtotal (95% CI)			**52.6%**	**0.87 [0.77 , 0.97]**

Heterogeneity: $Tau^2 = 0.03$; $Chi^2 = 47.33$, df = 13 ($P < 0.00001$); $I^2 = 73\%$

Test for overall effect: Z = 2.45 (P = 0.01)

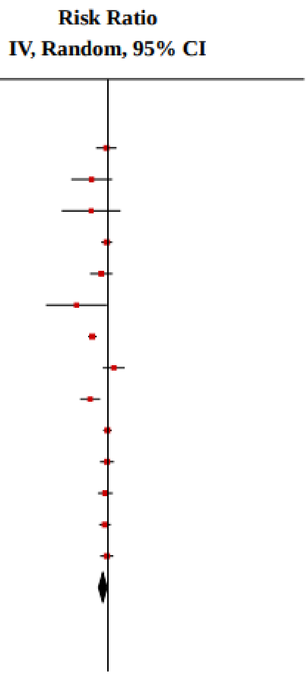


Figure 1. Effect of sanitation interventions on child diarrhea (meta-analysis)

Source: Bauza V, Ye W, Liao J, Majorin F, Clasen T. Interventions to improve sanitation for preventing diarrhoea. Cochrane Database of Systematic Reviews 2023, Issue 1. Art. No.: CD013328. DOI: 10.1002/14651858.

Investigation within the 'black box' of the results chain

Figure 2. presents the outcomes of the trials at each stage. From the perspective of the results chain, it is understandable why the Bangladesh WASH Benefit trial was successful in reducing child diarrhea, while others were not. This trial demonstrated a successful interruption of faecal-oral transmission, as evidenced by the reduction of faeces on the latrine floor. It achieved over 70% access among participants, but it does not indicate community-wide coverage. Most trials did not report on the effect of sanitation on interrupting transmission. A small number of trials did measure this but found that the latrines used in the trials were not effective in interrupting faecal-oral transmission of pathogens. This ineffectiveness could potentially

explain why there was no observed effect of sanitation intervention on the reduction child diarrhea.

Here are the key findings from Figure 2 based on scrutinizing the ‘black box’ of the results chain.

① Intermediate indicators such as latrine quality and collective level intermediate outcomes were not always measured. From the intermediate indicators that were reported, it appears that most trials were unsuccessful in achieving these intermediate outcomes. For example, the trial by Sinharoy et al. (2017), in which no effect was detected, indicated that none of the reported intermediate outcomes met with success. Consequently, it is plausible that these trials had minimal or no effect on child diarrhea.

② Of the 13 trials, the latrine in the Bangladesh trial was one of the most advanced in terms of the quality or structure of the latrine, and it was the one of the two trials that reported a reduction in the presence of faeces on the latrine floor. Cha et al. (2021) also found a significant decrease in faeces presence on the latrine floor in the intervention compared to control group.

Meanwhile, the trial conducted by Pickering et al. (2015) yielded positive results for some intermediate outcomes such as the absence of flies in the latrine, appropriate disposal of child faeces, and the presence of adequate handwashing facilities. However, it did not achieve sufficient coverage in terms of latrine access and use, which could likely be the primary reason for the lack of effect on child diarrhea. The trial by Humphrey et al. (2019) in Zimbabwe demonstrated a relatively successful performance in latrine access and use, but it did not result in a reduction in child diarrhea. However, their intervention was household-based, not community-based, so the reported percentage of latrine ownership and use was not indicative of community coverage.

Ventilated improved pit latrines were constructed by community builders in the target households, not across the entire communities. Furthermore, open defecation remained at around 40% in the intervention group even after the intervention (Humphrey et al, 2019), which could be contributing factor to the lack of effect. In addition, although the ventilated improved pit latrine was relatively superior among a range of pit latrines, it is questionable whether it effectively prevented contact with flies and faeces on the latrine floor and yard, or facilitated adequate handwashing behaviors after defecation by providing appropriate handwashing facilities. Given the high proportion of latrine access and use in the trial by Humphrey et al. (2019), the latrine's low performance could likely have been another cause of the lack of effect. As for the trials by Sinharoy et al. (2017), Quartocchi et al. (2021), and Cameron et al. (2013), it is relatively more evident than in other trials that their interventions had no effect, as there was no significant effect on any intermediate outcomes. The study by Hammer and Spears (2016) provides very limited information and it is hard to analyze from this framework.

	Logical Framework: Result Chain	Luby (2018)	Sinharoy (2017)	Humphrey (2019)	Null (2018)
Output/Activity Did the household have an improved toilet?	Simple pit toilet				
	(JMP) pit latrine with slab				
	Pit latrine with slab, floor, wall, roof				
	Pit latrine with slab, and lid				
	Ventilated (improved) pit latrine				
	A pour-flush				
	Flush toilet with water sealed				
Intermediate 1 (latrine quality) Did the latrine interrupt transmission of faeces?	Reduction in fly numbers (or fly presence) (Statistically significant reduction in the intervention compared to the control group)				
	Reduction of faeces on latrine floor (Statistically significant reduction in the intervention compared to the control group)				
	Reduction of faeces in household yard (Statistically significant reduction in the intervention compared to the control group)				
	Reduction of child faeces disposal to yard (Statistically significant reduction in the intervention compared to the control group)				
	Hand-washing facilities (regardless the presence of soap and/or water) (Statistically significant increase in the intervention compared to the control group)				
	Reduction of faeces on finger (hand-washing facilities with soap and water) (Statistically significant reduction in the intervention compared to the control group)				
Intermediate 2 (access, use, collective behavior)	Was the latrine coverage higher in the intervention than the control? (Statistically significantly higher in the intervention than the control)				
	Was the latrine coverage high enough in the intervention? (more than 70%)				
	Was the child faeces disposed appropriately in the intervention compared with control? (Was it significantly higher in the adequate disposal of child faeces in the intervention compared to the control group based on the self-report)?				
	Was the child faeces disposed appropriately in the intervention compared with control? (Was it higher in the adequate disposal of child faeces in the intervention compared to the control group based on direct observation)?				
	Was the percentage of use higher in the intervention than the control? (Was the percentage of use statistically higher in the intervention than the control group based on self-report)?				
	Was the percentage of use higher in the intervention than the control? (Was the percentage of use statistically higher in the intervention than the control group based on the direct observation)?				
	Was the percentage of use high enough in the intervention? (more than 70%)				
	Was the open defecation practices lower in the intervention compared with the control? (Was the open defecation practices statistically lower in the intervention compared with the control based on the self-report?)				
	Was the open defecation practices lower in the intervention compared with the control? (Was the open defecation practices statistically lower in the intervention compared with the control based on direct observation?)				
	Was the TOTAL sanitation achieved? (Total sanitation is operationally defined as none practicing open defecation and everyone using a household latrine in this study.)				
Outcome	Was there reduction in child diarrhea in the intervention compared to the control? (Was there statistically significant reduction in child diarrhea in the intervention than the control group?)				

	Logical Framework: Result Chain	Quarttrochi (2021)	Clasen (2014)	Pickering (2015)	Cameron (2013)
Output/Activity Did the household have an improved toilet?	Simple pit toilet				
	(JMP) pit latrine with slab				
	Pit latrine with slab, floor, wall, roof				
	Pit latrine with slab, and lid				
	Ventilated (improved) pit latrine				
	A pour-flush				
	Flush toilet with water sealed				
Intermediate 1 (latrine quality) Did the latrine interrupt transmission of feaces?	Reduction in fly numbers (or fly presence) (Statistically significant reduction in the intervention compared to the control group)				
	Reduction of feces on latrine floor (Statistically significant reduction in the intervention compared to the control group)				
	Reduction of feces in household yard (Statistically significant reduction in the intervention compared to the control group)				
	Reduction of child feces disposal to yard (Statistically significant reduction in the intervention compared to the control group)				
	Hand-washing facilities (regardless the presence of soap and/or water) (Statistically significant increase in the intervention compared to the control group)				
	Reduced fecal contamination on hands (hand-washing facilities with soap and water) (Statistically significant reduction in the intervention compared to the control group)				
Intermediate 2 (access, use, collective behavior)	Was the latrine coverage higher in the intervention than the control? (Stastistically significantly higher in the intervention than the control)				
	Was the latrine coverage high enough in the intervention? (more than 70%)				
	Was the child feces disposed appropriately in the intervention compared with control? (Was it significantly higher in the adequate disposal of child feces in the intervention compared to the control group based on the self-report)?				
	Was the child feces disposed appropriately in the intervention compared with control? (Was it higher in the adequate disposal of child feces in the intervention compared to the control group based on direct observation)?				
	Was the percentage of use higher in the intervention than the control? (Was the percentage of use statistically higher in the intervention than the control group based on self-report)?				
	Was the percentage of use higher in the intervention than the control? (Was the percentage of use statistically higher in the intervention than the control group based on the direct observation)?				
	Was the percentage of use high enough in the intervention? (more than 70%)				
	Was the open defecation practices lower in the intervention compared with the control? (Was the open defecation practices statistically lower in the intervention compared with the control based on the self-report?)				
	Was the open defecation practices lower in the intervention compared with the control? decrease (Was the open defecation practices statistically lower in the intervention compared with the control based on the self-report?)				
	Was the TOTAL sanitation achieved? (Total sanitation is defined that all the people in a community stop practicing open defecation.)				
Outcome	Was there reduction in child diarreha in the intervention compared to the control? (Was there statistically significant reduction in child diarrhea in the intervention than the control group?)				

	Logical Framework: Result Chain	Patil (2014)	Dickinson (2015)	Hammer (2016)	Briceno (2017)	Cha (2021)
Output/Activity Did the household have an improved toilet?	Simple pit toilet					
	(JMP) pit latrine with slab					
	Pit latrine with slab, floor, wall, roof					
	Pit latrine with slab, and lid					
	Ventilated (improved) pit latrine					
	A pour-flush					
	Flush toilet with water sealed					
Intermediate 1 (latrine quality) Did the latrine interrupt transmission of feaces?	Reduction in fly numbers (or fly presence) (Statistically significant reduction in the intervention compared to the control group)					
	Reduction of feces on latrine floor (Statistically significant reduction in the intervention compared to the control group)					
	Reduction of feces in household yard (Statistically significant reduction in the intervention compared to the control group)					
	Reduction of child feces disposal to yard (Statistically significant reduction in the intervention compared to the control group)					
	Hand-washing facilities (regardless the presence of soap and/or water) (Statistically significant increase in the intervention compared to the control group)					
	Reduced fecal contamination on hands (hand-washing facilities with soap and water) (Statistically significant reduction in the intervention compared to the control group)					
Intermediate 2 (access, use, collective behavior)	Was the latrine coverage higher in the intervention than the control? (Stastistically significantly higher in the intervention than the control)					
	Was the latrine coverage high enough in the intervention? (more than 70%)					
	Was the child feces disposed appropriately in the intervention compared with control? (Was it significantly higher in the adequate disposal of child feces in the intervention compared to the control group based on the self-report)?					
	Was the child feces disposed appropriately in the intervention compared with control? (Was it higher in the adequate disposal of child feces in the intervention compared to the control group based on direct observation)?					
	Was the percentage of use higher in the intervention than the control? (Was the percentage of use statistically higher in the intervention than the control group based on self-report)?					
	Was the percentage of use higher in the intervention than the control? (Was the percentage of use statistically higher in the intervention than the control group based on the direct observation)?					
	Was the percentage of use high enough in the intervention? (more than 70%)					

	Was the open defecation practices lower in the intervention compared with the control? (Was the open defecation practices statistically lower in the intervention compared with the control based on the self-report?)
	Was the open defecation practices lower in the intervention compared with the control? decrease (Was the open defecation practices statistically lower in the intervention compared with the control based on the self-report?)
	Was the TOTAL sanitation achieved? (Total sanitation is defined that all the people in a community stop practicing open defecation.)
Outcome	Was there reduction in child diarreha in the intervention compared to the control? (Was there statistically significant reduction in child diarrhea in the intervention than the control group?)

Figure 2. Results of investigation inside the results chain (Green: met with success; Red: not met with success; Black: not reported; Yellow: reported but hard to describe it. Success criteria is described in each column of the result chain inside the bracket. The studies by Null (2018), Luby (2018) and Humphrey (2019) did not include community-wide coverage, but instead focused on the proportion of participants with household latrines.)

Performance of interventions on intermediate outcomes (collective level: latrine coverage and latrine use, and open defecation)

Performance of interventions on intermediate outcomes are explained in the Table 4. As described below, low performance of interventions on intermediate outcomes might be probable reasons of lack of effect in some trials.

In the study conducted in India by Clasen et al. (2014), the proportion of households utilizing latrines remained low even after the intervention, with only 36% in the intervention group and 9% in the control group. The WASH Benefits trial in Kenya, led by Null et al. (2018), revealed that latrine coverage among the participants was already exceptionally high before the intervention began, with 94% in the intervention group and 95% in the control group. Another RCT carried out in Tanzania by Briceno et al. (2017) found no effect of combining CLTS with sanitation marketing on diarrhea prevalence. In this study, latrine coverage and usage were slightly higher in the intervention group compared to the control group.

In a trial of TSC conducted in India, Patil and colleagues (2014) found no significant effect, with only a small percentage of households using latrines even after sanitation promotion (27% in the intervention and 17% in the control group). In contrast, the WASH Benefits trial in Bangladesh (Luby et al., 2018) demonstrated a significant effect of a sanitation intervention on diarrhea, with high latrine coverage following the promotion (97% among the participants in the intervention and 31% in the control group) although it is not a community-wide coverage. The proportion of latrine use was also high in this trial (94% among the participants in the intervention; 40% in the control group). The baseline value (54%) for household latrine coverage in the WASH Benefit trial in Bangladesh (2018) was lower than that of the WASH Benefit study in Kenya (81%) (2018), indicating substantial room for further improvement. In a trial conducted in East Java, Indonesia, Cameron and colleagues (2013) reported a substantial but statistically non-significant effect on child diarrhea (risk ratio=0.64, 95% CI, 0.36–1.13) (Bauza et al., 2023). In this trial, latrine coverage was 70% and 65% in the intervention and the control groups, respectively, and latrine use was 43% and 44%, respectively following the intervention.

The RCT conducted in Mali by Pickering and colleagues (2015) revealed no significant effect of CLTS on diarrhea. The intervention substantially increased access to latrines (doubled it) and the latrines were used so latrine usage was twice as high in the treatment group. The latrines in the intervention group demonstrated superior performance in terms of fewer flies present, less faecal matter in the household yard, and better-equipped handwashing facilities with soap and water. However, there was no significant difference in the presence of faecal matter on the latrine floor. Additionally, the researchers reported no discernible differences in use of latrine with concrete slab between intervention and control group based on latrine observations. Most latrines constructed during the Mali trial did not meet the criteria of improved facility defined by WHO/UNICEF's Joint Monitoring Program. The absence of any significant effect may be partially attributed to the lack of any significant differences on the presence of faecal matter on the latrine floor and quality latrine.

In the CLTS trial conducted in Ethiopia (Cha et al., 2021) found significant reduction in presence of flies around the pit hole and feaces on the floor of latrines in the intervention compared to the control group. However, They did not detect significant difference in feces inside and outside of household compound, as well as adequate disposal of child feces. In their trial, the coverage of any type of latrine was high in both intervention and control, but the improved latrine that they operationally defined for the trial (study-improved latrine) was 35% and 2.8% in the intervention and control communities, respectively, at 10 months after the CLTS triggering. Use of any type of latrine was not different but use of study-improved latrine was higher in the intervention than control group. Based on the results chain, the results in the intermediate outcomes in the Ethiopia CLTS trial were only partially successful. Longitudinal prevalence and incidence of child diarrhea were significantly lower in the intervention group than those in the control group. Period prevalence of child diarrhea was not significantly different between the two groups.

The methods used to measure latrine ownership and use in the RCTs included in this study were inconsistent. The definitions of what constitutes an acceptable type of latrine were not thoroughly documented. RCTs that adequately assessed the key structural components of a latrine such as pit-depth, pit-hole cover, slab, wall, roof, door, and handwashing facility with soap were few. In the Bangladesh trial, the latrine was a double pit latrine with a water seal (Luby et al., 2018), while in the Kenya trial, latrines were upgraded to improved versions featuring a plastic slab and a tight-fitting lid over the hole (Null et al., 2018). The Mali trial (Pickering et al., 2015) did not define what could be considered an acceptable type of latrine, even though they did assess latrine structure.

Trials have reported varied results regarding the effect of sanitation interventions on open defecation practices. The extent of latrine coverage at the community level has frequently been used as a surrogate indicator for these practices. Another common measure for determining open defecation free status was the percentage of individuals openly defecating within a community. A trial conducted in Indonesia (Cameron et al., 2013) noted a decrease in open defecation practices. The trial in Mali (Pickering et al., 2015) reported a reduction in open defecation in the intervention group based on household surveys. However, the open defecation free status was determined based on government reports dealing with the certification of open defecation free status of villages. It is challenging to come to a definitive conclusion regarding the impact of sanitation interventions on open defecation practices or open defecation free, given the diversity in definitions and methods for assessing open defecation-free status, and the inconsistent criteria for verifying and certifying open defecation-free across different studies. Moreover, open defecation status was typically measured at the household or individual level, rather than at the community level. To achieve, "total sanitation", open defecation must be eradicated at the community level. Therefore, open defecation should be identified and addressed primarily at the community level rather than the household level. Out of 13 trials, no trial appeared to achieve "total sanitation".

Performance in intermediate outcomes (latrine quality)

I reviewed the results of sanitation interventions aimed at disrupting the pathway of faecal contamination. This was measured by the presence of faeces on the floor and yard, the count of flies inside the latrine, and availability of appropriate hand-washing facilities. Most of the trials did not detect a significant effect on these the intermediate outcomes, or they did not measure them at all. The RCTs conducted in rural India (Clasen et al., 2014) and Tanzania (Briceno et al., 2017) found no effects of sanitation promotion on the number of flies inside latrines or food preparation areas, nor on the presence of faeces within the household compound or latrine. They also found no effect of the intervention on the presence of faeces on the latrine. However, they did find a significant effect of the intervention on the number of flies in the latrine and the presence of faeces in the household compound. In the Ethiopia CLTS trial, Cha et al. (2021) found a significant effect of an intervention on the presence of feces on the latrine and flies around the pit hole, but no effect was detected on the presence of feces inside and outside of the household compound.

2.2. Review of economic evaluations of sanitation interventions

2.2.1. Background

Various agendas in the field of development are vying for resource allocation. The most effective tools for informing decisions about resource allocation are cost-benefit or cost-effectiveness analyses, especially for interventions backed by governments (Drummond et al., 2015).

Many studies have described limitations of economic evaluations (Jenkins et al., 2019; Weintraub & Cohen, 2009; Damart & Roy, 2006). For instance, Damart and Roy (2006) articulated limitations of cost-benefit analysis in terms of the realization of public choices. They questioned the objectivity of the CBA procedure arguing that converting values into monetary or quantitative form is largely arbitrary and sometimes reflect political positions. The impossibility of obtaining intrinsic values for phenomena in a society at a given time point cause imperfect measurements. They argue that 'an exhaustive and completely unbiased study of the costs and benefits' is unrealistic in every investment project, and CBA procedures are "not exempt from important biases which distort the choices resulting from the socio-economic evaluation of investment projects." Taking an example of decision making about public transportation, multiple and varying impacts on the environment including air and noise pollution and living conditions of the inhabitants are hard to monetize or quantify. They highlighted the importance of reconciliation between economic evaluation and public debate during the decision-making process.

Still, understanding the costs, benefits, and effectiveness of CLTS interventions can assist in making informed decisions about resource allocation. However, cost-benefit or cost-effectiveness analyses of sanitation interventions based on empirical estimation are scarce. The health sector in low- and middle-income countries has increasingly well-developed institutions for applying cost-effectiveness analysis in decision-making for interventions where averted DALYs are the main or only benefit (Falkowski et al., 2023; The International Decision

Support Initiative (iDSI): www.idsihealth.org). However, the WASH sector does not yet have this culture (Falkowski et al., 2023).

According to a review by Hutton and Chase (2016) on the costs and benefits of sanitation, most previous studies were based on modelling exercises or ex-ante cost-benefit analyses and relied heavily on assumptions to estimate parameter values. These previous modelling-based studies (Hutton and Haller, 2007; Hutton, 2013; Hutton, 2015) point to the need for empirical research because costs and benefits are highly variable depending on the context. Radin and colleagues conducted a review of studies that compared the costs and benefits of sanitation interventions including a CLTS intervention (Radin et al., 2020). They identified 14 cost-benefits analyses. Ross carried out a systematic review of cost-benefit and cost-effectiveness analyses of water, sanitation, and hygiene interventions (Ross, 2021), selecting 34 studies for review. To the best of my knowledge, Ross's 2021 study represents the most recent systematic review of cost-benefit and cost-effectiveness analyses related to water, sanitation, and hygiene interventions.

In this part of Chapter 2, I aim to review economic evaluations of sanitation interventions.

2.2.2. Search strategy

Radin et al. (2020) did not provide details regarding their search strategy, selection criteria, or quality assessment. In contrast, Ross (2021) thoroughly outlined the review methods, including search strategy. In this section of Chapter 2, I have endeavoured to avoid duplicating existing reviews. Instead, I have primarily focused on assessing the estimation methods used in existing economic evaluations. This approach aims to address methodological research gaps and pave the way for further studies. As for the economic evaluation of a CLTS intervention conducted in SNNPR, Ethiopia, I have provided more extensive details in other chapters of my DrPH thesis. Table 5 presents a summary of the search strategy employed in the most recent review of economic evaluations of water, sanitation, and hygiene interventions (Ross, 2021).

Table 5. Summary of methods applied in the latest review (Source: Ross, 2021)

Category	Details
Eligibility criteria	Interventions in water supply and distribution, water quality, and sanitation in any low- and middle-income countries; Interventions targeting individuals, households and communities, but not at schools and healthcare facilities; Outcomes include any measures that are the output of full economic evaluation, such as benefit-cost ratio or cost per disability-adjusted life year (DALY) averted.
Information sources and searches	Titles and abstracts of peer-reviewed and grey literature for publications since January 1980, combining terms for (A) CBA or CEA, with terms for (B) water supply and distribution, or water quality and treatment, or sanitation were searched; Database: Medline, Embase, Global Health, EconLit, Web of Science, and 17 additional websites and databases. In addition, 53 individuals were contacted.
Studies selected	53 publications included in his review • 31 used cost benefit analysis • 15 used cost-effectiveness analysis • 7 used both analyses • 20 evaluated empirical interventions • 7 used data from an impact evaluation • 34 evaluated an intervention for improving sanitation
Quality assessment	The Consolidated Health Economic Evaluation Reporting Standards (CHEERS) with a set of 24 criteria were used. Studies were awarded 1 point for each CHEERS item that was fully met, 0.5 for each partially met, and 0 when not met or insufficient information was reported. Studies scoring 80% or more were categorised as “very high” quality, those scoring 65-79% as ʺhigh”, 50-64% as “medium” and less than 50% as “low”; Eight (8) studies (15%) were scored as very high quality, 11 (21%) as high, 26 (43%) as medium, and 8 (15%) as low.

I reviewed all of the studies identified in two recent reviews (Radin et al., 2020; Ross, 2021). In addition, I added recent studies on cost-benefit and cost-effectiveness analyses by adapting search strategy described by Ross (2021) to only sanitation interventions and extending the search period to April 2023. Finally, I included 37 studies in this review, of which 27 were cost-benefit and 15 were cost-effectiveness studies (five studies conducted both cost-benefit and cost-effectiveness analyses). In the recent review by Ross (2021), 25 cost-benefit and 14 cost-effectiveness studies on sanitation intervention were selected.

2.2.3. Cost and benefits of sanitation interventions

Out of the 27 cost-benefit analysis results, 10 were published in peer-reviewed journals as shown in Table 6. The other 17 results were not published in peer-reviewed journals. Out of these 7 were World Bank reports (Hutton et al., 2008; Winara et al., 2011; Rodriguez et al., 2011; Chuan et al., 2012; Anh et al., 2012; Heng et al., 2012; Rodriguez et al., 2013), 8 were Copenhagen Consensus Center reports (Rijsberman & Zwane, 2012; Hutton, 2015; Larsen et al., 2016; Sklar, 2017; Whittington et al., 2017; Larsen, 2018a; Larsen, 2018b; Dwumfour-Asare, 2020). The other two studies that were not published in peer-reviewed journals were sponsored by the WHO (Hutton et al., 2007) and the United Nations Children's Fund (Hutton, 2018). The reports may have undergone internal reviews, but, on the whole, the lack of a standard peer-review process may have impacted on the quality of these analyses.

All the cost benefit studies included in this review that were conducted by the World Bank, WHO, or UNICEF were either undertaken or supervised by Guy Hutton (Table 6). Five cost-benefit analyses were also conducted or supervised by Dale Whittington (Table 6).

All studies included both health benefits, such as reductions in morbidity and mortality, and time savings resulting from the transition from open defecation spots or shared sanitation facilities to household latrines. The studies conducted or overseen by Dale Whittington suggested that direct health effects constituted the majority of benefits (57–62% of benefits). Conversely, the studies conducted or supervised by Guy Hutton proposed that the primary benefits were time savings (67–83%) derived from no longer needing travel to a location away from home for defecation, although there were exceptions in China, Vietnam, and Cambodia

(Figure 3). Most studies relied on various assumptions to estimate the amount of time saved, rather than collecting primary data.

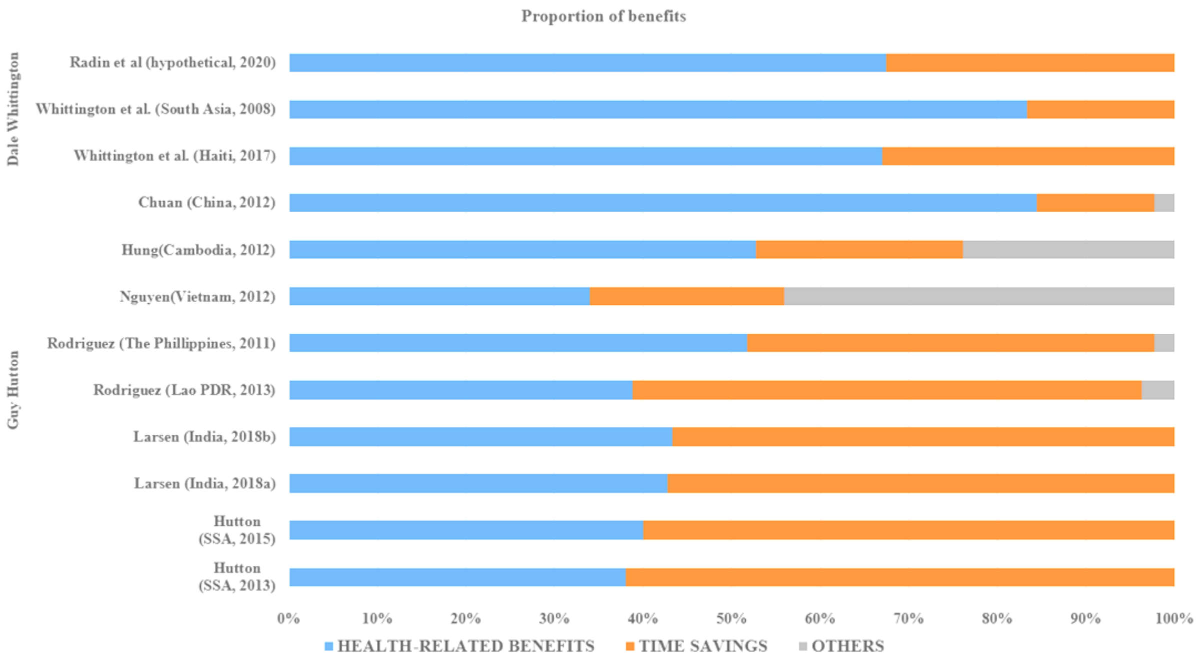


Figure 3. Proportion of benefits (health-related benefits, time savings, and others; some studies did not show the breakdown of benefits.)

Estimation of health effects

All cost-benefit analyses included in this review utilized existing literature to estimate the health effects of sanitation interventions, without exception. The majority of these studies relied on the results of reviews or meta-analyses, which suggested a 36% or 28% point estimate of the relative reduction in diarrhea. These estimates were higher than those of the most recent meta-analysis, which was based solely on an RCT. The risk ratios for diarrhea prevalence in under-five children were 0.98 (95% CI, 0.83 –1.16) from providing access to any sanitation facility, 0.85 (95% CI, 0.69–1.06) from improving sanitation facilities, and 0.82 (95% CI, 0.69–0.98) from interventions that only involved behaviour-change messaging (Bauza et al, 2023).

Six studies estimated the benefits and costs at global, regional, or country levels using hypothetical base parameters. Some of theses studies employed mixed methods to estimate benefits and costs, utilizing both hypothetical predictions and field-based data collection (Winara et al., 2011; Rodriguez et al., 2011; Chuan et al., 2012; Anh et al., 2012; Heng et al., 2012; Rodriguez et al., 2013). Dickinson et al. (2015) opted to use the pooled effect from a meta analysis of existing reviews to estimate the reduction in diarrhea cases for their benefit-cost analysis rather than relying on the results of their own trial.

When incorporating health effects into the benefit estimation, some studies have focused solely one diarrhea, while others have broadened their scope to include diseases such as malaria, acute respiratory infection, measles, helminthiasis, and malnutrition (Hutton et al., 2008; Winara et al., 2011; Rodriguez et al., 2011; Rodriguez et al., 2013; Hutton, 2013; Cronin et al., 2013; Hutton, 2015; Dickinson et al., 2015; Larsen et al., 2016; Larsen et al., 2018b).

As shown in Figure 3, the extent of each component's contribution to the overall benefit varied across the studies.

Coverage

Both the costs and benefits of sanitation intervention could be influenced by the actual change in coverage following an intervention (Radin et al, 2020). However, many studies have based their coverage changes on hypothetical estimation rather than on primary data collection. Some even projected hypothetical coverage scenarios, such as MDG coverage or universal coverage, following interventions (Hutton et al., 2007; Hutton, 2015; Hutton et al., 2007a; Hutton et al., 2007b; Hutton et al., 2011; Larsen, 2016). Some studies claimed to use "actual coverage", but these were based on observational studies, not experimental ones (Whittington et al., 2009; Winara et al., 2011; Heng et al., 2012; Rijsberman & Zwane, 2012; Whittington et al., 2012; Chuan et al., 2012; Anh et al., 2012; Heng et al., 2012; Rodriguez et al., 2013; Sklar, 2017;

Whittington et al., 2017; Hutton, 2018; Larsen, 2018a, b; Rodriguez et al., 2011). This method has limitations, as it may not accurately assess a net increase in coverage or usage by a specific intervention, given that it does not consider any counterfactual.

Externalities

Sanitation might have externalities when it reaches a certain level (Fuller and Eisenberg, 2016), which however remains poorly defined given the paucity of evidence. These externalities were not factored into the estimation of benefits and costs until recently. Radin et al. (2020) computed the benefits for villages both with and without the external effect of sanitation, taking into account the level of coverage.

Units for cost-benefit analyses

Radin et al. (2020) pointed out that many existing studies have used the household as the unit for estimating costs and benefits. This approach may have resulted in less accurate calculation, as many sanitation interventions are conducted at the community level, not just the household level. Furthermore, health effects can occur community-wide when coverage reaches a certain threshold (Fuller and Eisenberg, 2016). This suggests that the costs and benefits for those who did not comply with the intervention should also be considered. Specifically, when calculating the benefits and costs of a CLTS intervention, the primary unit of analysis should be the community, not the household, as it is primarily based on community-wide collective behavior change, not individual households. However, existing studies have estimated the health benefits for only those who adopted household latrines, regardless of coverage, with the exception of the studies by Radin et al. (2020) and Hutton (2018).

Age categories of the beneficiaries of health effects

While most studies included all age groups as beneficiaries, some studies included only under-five children (Larsen et al., 2016; Whittington et al., 2017; Larsen et al., 2018a.), and some others did not specify the age groups of the beneficiaries (Dasgubta et al., 2020; Dickinson et al., 2015; Dwumfour-Asare, 2020; Rijsberman and Zwane, 2012).

Lifespan of a latrine and discount rate

The heterogeneity of results in cost-benefit analyses, particularly in terms of the benefit share of each component, may have partially stemmed from varying assumptions about life span and discount rates. The time horizons and discount rates used in these studies varied significantly, ranging from 1 to 20 years and from 0% to 20%, respectively.

Cost

Most studies included the costs of infrastructure, maintenance, and operation. However, few of the studies provided detailed, item-by-item cost breakdowns. For example, while all the studies mentioned the capital costs, it was unclear whether these costs pertained solely to sanitation facilities or also encompassed other capital costs such as vehicles and/or motorcycles for project management, monitoring, and community mobilization. The majority of the studies failed to account for the time spent by CLTS facilitators, government officials, health personnel, and community members on various intervention-related activities such as community mobilization. They also did not include additional costs such as training, stakeholder meetings, monitoring, and administrative work for interventions, with the exception of Radin et al. (2020).

Intervention and latrine type

Most studies examined the benefits and costs of sanitation improvements, ranging from the transition from open defecation to the use of sanitation facilities, or enhancements to existing sanitation facilities. Certain studies investigated the benefits and costs of CLTS (Rijsberman and Zwane, 2012; Whittington et al., 2008; Whittington et al., 2017; Radin et al., 2020a; Radin et al., 2020b). The World Bank has conducted investigations into the benefits and costs of sanitation interventions, considering a variety of changes along the sanitation ladder, starting from open defecation. For example, reports from Lao (Rodriguez et al., 2013) and The Phillippines (Rodriguez et al., 2011) presented economic analyses for three or five different options, including the transition from open defecation to basic sanitation, such as the use of a dry pit in rural. While some studies specified the type of latrine used, others did not, instead opting to use the more general term, “basic sanitation”.

Others

World Bank studies have identified key components of benefits in in China (Chuan et al., 2012), Vietnam (Anh et al., 2012), and Cambodia (Heng et al., 2012). In China, the primary benefit was found to be savings on medical expenditures (Chuan et al., 2012). In Vietnam, the main advantage was the cost savings for water treatment (Anh et al., 2012). In Cambodia, the significant benefit was the time saved by no longer needing to walk to fetch clean water following sanitation interventions (Heng et al., 2012). In studies conducted in Vietnam and Cambodia, it was believed that improved sanitation could lead to a better quality water source due to less contamination of water. This would not only save people time in accessing water sources, but also reduce costs associated with water treatment.

These benefits were not included in other cost-benefit analyses. Other benefits, such as safety, dignity, and convenience were identified in some studies (Hutton, 2018), but these were not monetized in the estimations of benefits and costs.

Table 6. Cost benefit analysis of sanitation interventions

No.	Authors (year)	Country (Area)	Intervention/ latrine type	Age groups benefitted health effect	Change in coverage usage	Health effects for benefit calculation	Life span	Discount rate	Methods	Results	Remarks
1	Hutton et al. (2007a)	Global	Water supply and sanitation (combined)	All ages	Universal coverage; MDGs target	Diarrhea: 38% reduction	20	3%	Hypothetical	BCR 5.2 for Africa (universal coverage)	Journal of Water and Health
2	Hutton et al. (2007b)	Global	Simple pit latrine & others	All ages	Universal coverage; MDGs target	Diarrhea: 38% reduction for improved sanitation	20	3%	Hypothetical	6.6 for MDA target; 6.5 for universal	World Health Organization
3	Hutton et al. (2008)	Cambodia Indonesia Phillippines Vietnam	Improved latrine	All ages	Universal coverage	Diarrhea (attributable fraction of diarrhea to poor sanitation: 88%) and other disease (ARI, malaria, measles, malnutrition)	-	3%	Based on national data	Overall impact was described	World Bank
4	Winara et al. (2011)	Indonesia	6 options including pit latrine	All ages	100% improved sanitation (ideal and actual)	36% relative reduction in diarrhea; and other diseases helminthes, hepatitis A and E, trachoma, scabies, malnutrition and diseases related to malnutrition (malaria, acute lower respiratory infection, Measles)	5 years (dry pit)	8%	Empirical intervention but relied on review for effect estimation	BCR: 7~8 for pit latrine in rural areas	World Bank (Guy Hutton led the development of the concept and methodology)
5	Rodriguez et al. (2011)	The Philippines	5 options including pit latrine	All ages	100% improved sanitation (ideal and actual)	36% relative reduction in diarrhea; Other diseases (helminthes and	1 year for dry pit; others for 20 years	8%	Empirical intervention but relied on review for effect estimation	BCR:4.7 (Actual setting)	World Bank (Guy Hutton led the development of the

No.	Authors (year)	Country (Area)	Intervention/ latrine type	Age groups benefitted health effect	Change in coverage usage	Health effects for benefit calculation	Life span	Discount rate	Methods	Results	Remarks
						diseases related to malnutrition. malaria, acute lower respiratory infection, measles, etc.)					concept and methodology)
6	Chuan et al (2012)	China	4 options including pit latrines	All ages	100% improved sanitation (ideal and actual)	36% reduction in diarrhea (basic sanitation alone)	10 years for pit latrine	8%	Empirical intervention but relied on review for effect estimation	BCR: 8.9(actual setting)	World Bank (Guy Hutton led the development of the concept and methodology)
7	Anh et al. (2012)	Vietnam	5 options including flush to pit	All ages	100% improved sanitation (ideal and actual)	36% reduction in diarrhea (basic sanitation alone)	7 years For rural wet pit latrine	8%	Empirical intervention but relied on review for effect estimation	BCR:3.2 (actual setting)	World Bank (Guy Hutton led the development of the concept and methodology)
8	Heng et al (2012)	Cambodia	3 options including pit latrine	All ages	100% improved sanitation (ideal and actual)	36% reduction in diarrhea (basic sanitation alone) (regardless of coverage?)	1 for CLTS dry pit; 3 for concrete ring dry pit; 8 for rural wet pit	8%	Empirical intervention but relied on review for effect estimation	BCR:1.4-2.0 (ideal) 0.84-1.3(actual) page 82	World Bank (Guy Hutton led the development of the concept and methodology)
9	Rijsberman and Zwane (2012)	Global	CLTS++ (wet pit latrine)	Not explained	Cover 50% of people without access	Not explained	10	8	Hypothetical	BCR:4-7	Copenhagen Consensus Center
10	Rodriguez (2013)	Lao PDR (rural & urban)	3 options including pit latrine	All ages	100% improved sanitation	36% reduction in diarrhea;	1 year for dry pit,		Empirical intervention but relied on review	BCR:9.0 for rural	World Bank (Guy Hutton led the development of the

No.	Authors (year)	Country (Area)	Intervention/ latrine type	Age groups benefitted health effect	Change in coverage usage	Health effects for benefit calculation	Life span	Discount rate	Methods	Results	Remarks
						Episodes/cases per person-year not described (not segregated for age groups), duration not described. No incidence, cases, episodes, or durations are described. helminths, and malnutrition-related diseases such as malaria, acute lower respiratory infection (ALRI) and measles	others for 20 years		for effect estimation	(dry pit latrine)	concept and methodology)
11	Hutton et al. (2020)	India	(now checking)	All ages	ODF & partial ODF	47% reduction in ODF scenario 34% reduction in partial ODF scenario (he considered different cases of diarrhea per year)	10	8%	Empirical intervention but relied on review for effect estimation	BCR: 4.0	World Development
12	Whittington et al (2008)	South Asia	CLTS	All ages	40% uptake rate 70% usage rate	30% reduction; 4.5 cases per household per year Incidence: 0.9 cases per person per year	6	4.5%	Hypothetical;	BCR: 3.0	Foundations and Trends in Microeconomics
13	Whittington et al (2012)	Developing countries	Total sanitation	All ages	20-60% uptake 50-90% usage	30% reduction in diarrhea; 0.9 incidence diarrhea case per person year	3	4.5%	hypothetical	BCR: "-0.4~4.7"	World Development
14	Hutton (2013)	Global	Basic improved wet pit latrines	All ages	Universal/ MDG target	36% reduction in diarrhea Incidence (cases per person-year): not described	8	8%	hypothetical	BCR:5.5 (global) 2.8 for SSA	Journal of Water and Health

No.	Authors (year)	Country (Area)	Intervention/ latrine type	Age groups benefitted health effect	Change in coverage usage	Health effects for benefit calculation	Life span	Discount rate	Methods	Results	Remarks
						Malnutrition and other diseases including respiratory infection, malaria, measles and others are included.					
15	Cronin et al (2014)	India	5 options including Pour flush toilet with single leach pit	All ages	100% coverage	Diarrhea (attributable fraction of diarrhea to poor sanitation: 88%) And other diseases (ARI, measles, malnutrition, malaria)	15	3%	Empirical intervention and effect based on review	BCR:5.7	Journal of Water, Sanitation and Hygiene for Development (UNICEF) (Referred to Hutton et al. 2008)
16	Hutton (2015)	Global	Dry pit in rural/any pit latrine in urban (elimination of open defecation)	All ages	100 % coverage (from 50% at baseline)	28% reduction in diarrhea (improved on-site sanitation, no formal excreta management, 50% reduction in helminths	8	3%-5%	hypothetical	BCR:2.9-3.3 (2.9-3.2)	Copenhagen Consensus Center
17	Dickinson et al (2015)	India	Seemingly effect only on children?	-	-	30% reduction in diarrhea; Additional: nutritional improvements	6	20%	Empirical & literature review	BCR:1.64(unsubsidized);2.26 (subsidized)	Economic Development and Cultural Change
18	Larsen et al (2016)	Bangladesh	From unimproved to improved facility (private improved sanitation)	Children under-five	100% coverage (61% at baseline)	28% reduction in diarrhea (Prüss-Üstun et al. 2014) Other diseases (parasite infection, respiratory infection, malnutrition) are included.	15	5%	hypothetical	BCR:1.4~2.3	Copenhagen Consensus Center
19	Sklar (2017)	Haiti	Pit latrines with septic tanks	All ages	Cover all urban people	28% reduction in diarrhea	15	5%	Empirical	BCR:0.90	Copenhagen

No.	Authors (year)	Country (Area)	Intervention/ latrine type	Age groups benefitted health effect	Change in coverage usage	Health effects for benefit calculation	Life span	Discount rate	Methods	Results	Remarks
					without access						Consensus Center
20	Whittington et al(2017)	Haiti	CLTS/ CLTS /potential interventions	Children under five	40% uptake 75% usage	① cases per person-year 25% reduction in diarrhea (3% disuse of latrine/year)	3	5%	hypothetical	BCR:1.1	Copenhagen Consensus Center
21	Larsen (2018a)	India rural/urban; Andra Pradesh	Sanitation improvement(&promotion of the use of sanitation facilities), Improved sanitation (a flush/pour-flush system with a single-or-twin-pit)	Children under five	95% (54% at baseline)	28% reduction 23% for shared sanitation (Pruss-Ustun et al. 2004; Wolf et al. 2014)	20	5%	hypothetical	BCR:7.8 for sanitation improvement in rural, 6.2 sanitation improvement in urban; 1.8 sanitation promotion	Copenhagen Consensus Center
22	Larsen (2018b)	India (rural/urban; Rajastan)	Sanitation improvement(&promotion of the use of sanitation facilities) Improved sanitation (a flush/pour-flush system with a single-or-twin-pit)	All ages	95% coverage	28% reduction 23% for shared sanitation Number of diarrheal episodes; average number of days of illness; (All ages?)	20	5%	hypothetical	BCR:9.0 for sanitation improvement in rural, 7.2 sanitation improvement in urban; 2.2 sanitation promotion	Copenhagen Consensus Center

No.	Authors (year)	Country (Area)	Intervention/ latrine type	Age groups benefitted health effect	Change in coverage usage	Health effects for benefit calculation	Life span	Discount rate	Methods	Results	Remarks
23	Hutton (2018)	India	Swachh Bharat Mission (Gramin)	All ages	68% increase	34% reduction in diarrhea; And other disease	10	8%	Empirical intervention; review for effect size	BCR:4.3	UNICEF
24	Dasgubta et al (2020)	India	Double-pit pour flush latrine/Eco-san	-	Not described	36% reduction(up to 36% is achievable through improved sanitation interventions) Diarrheal episodes per person year: 3	10	3%	Survey (some parameters) and literature review	BCR: 1.69 (3.3 for eco-san)	Climate and Development
25	Dwumfour -Asare (2020)	Ghana (Urban)	Toilet subsidy provision/subsidy with enforcement Assumption basis scenario (biodigester toilet)	-	1-20% of uptake rate for subsidy only/50-100% for subsidy with enforcement	30% reduction in diarrhea; Discount rate 8%	20	8%	hypothetical	4.14-5.13 for subsidy only; 3.87-4.55 subsidy with enforcement	Copenhagen Consensus Center/ Supervised by Larsen
26	Radin et al. (2020a)	Hypothetical areas	CLTS Assumption basis scenario	All ages	From 40% to 50%, 60% or 80%, 10%, 15% or 35% increase in use	20% relative reduction in diarrhea 2.4 episodes per year per person (U5C), 0.5 for 5-14 yrs; 1 for 15+)	5-10 years	0%-6%	hypothetical	BCR: 1.7(1.9 with externalities)	Journal of Benefit Cost Analysis
27	Radin et al. (2020b)	Ghana (rural)	CLTS/CLTS with subsidy	All ages	High, medium, and low uptake(35%, 15%, and 5%)	20-35% reduction in diarrhea	10	8%		BCR: 0.94 (all communities, CLTS only)	Journal of Water, Sanitation and Hygiene for Development

No.	Authors (year)	Country (Area)	Intervention/ latrine type	Age groups benefitted health effect	Change in coverage usage	Health effects for benefit calculation	Life span	Discount rate	Methods	Results	Remarks
Blank column: No information was found											

2.2.4. Cost-effectiveness analyses

The number of cost-effectiveness studies on sanitation improvement was smaller than that of cost-benefit analyses. In this review, I examined 15 cost-effectiveness studies (Table 7). Of these, 12 used health as an outcome measure of effectiveness, while the remaining three selected sanitation coverage or household latrine uptake. When quantifying health effects, some studies estimated the health improvement of children only (Spears, 2013; Meddings et al., 2004), while others included individuals of all ages.

Of the 12 cost-effectiveness studies that selected health as the outcome of effectiveness, three only included benefits derived from preventing deaths (i.e., mortality benefit) attributable to improved sanitation (Jha et al., 1994; Meddings et al., 2004; Spears, 2013). Spears et al. (2013) solely incorporated infant survival into benefit calculations, while Jha et al. (1994) and Meddings et al. (2004) estimated benefits exclusively from the survival of under-five children. These studies did not account for the health benefits experienced by individuals who, although they live, are afflicted by diseases.

Similar to cost-benefit studies, the time horizon utilized in cost-effectiveness analyses can vary. Meddings et al. (2004) estimated the number of deaths prevented by a sanitation intervention over a year. In contrast, Murray et al. (2004) calculated the benefits of a similar intervention over a span of 20 years.

When calculating costs, certain studies have only included expenditures directly related to program inputs such as infrastructure, public hygiene programmes, and maintenance costs (Murray et al., 2004). Other studies have incorporated household or village spending on latrines (Spears 2013; Meddings et al., 2004). Jha et al (1994) estimated cost-effectiveness of 40 different interventions including water and sanitation improvements in Guinea, based on a hypothetical scenario. However, no detailed explanations were provided regarding the calculation methods used, particularly in relation to water and sanitation improvements.

Cairncross et al. (2006) conducted a cost-effectiveness analysis that provided detailed parameter values for child diarrhea, including the number of episodes and duration of diarrhea per year among children, However, they did not provide explanations for diarrhea in other age groups, even though they factored in the health effects on all age groups when calculating cost-effectiveness. If they applied the same parameter values of child diarrhea to other age groups, the effectiveness might have been overestimated. Similar to the cost-benefit analyses, most studies, with the exception of Spears (2013), relied on literature reviews to estimate health effects, and they did not take coverage into account.

Overall, the review of cost-benefit and cost-effectiveness analyses reveals a research gap, particularly in the use of empirical basis parameter values for health effects and latrine coverage. My goal is to bridge this knowledge gap by estimating the costs and benefits of a sanitation intervention, using a trial conducted in Ethiopia as a basis.

Table 7. Cost-effectiveness analyses of sanitation interventions

	Authors	Country	Intervention	Age group	Coverage increase	Effect	Time horizon	Discount rate	Results	Source
1	Jha et al (1994)	Guinea	Construct pit latrines and provide safe water (hypothetical)	Under-five children	Not described	21% reduction (mortality reduction)	6 years	3%	343 US$ per life year saved	Health Policy and Planning
2	Murray et al (1998)	Not described	Standpipe and pit latrines in refugee camps;(choler vaccine)	All ages	Not described	27% reduction in diarrhea; 40% reduction in cholera	20	10%	Net cost per DALY averted: 276 (US$) in epidemic areas; 433 US$ in endemic areas DALY	WHO Bulletin
3	Meddings et al (2004)	Afghanistan	Construction of a latrine; renovation of an existing latrine	Children uder-5; Children up to11years	Not described	Child mortality reduction (235 for U5C; 285 U12C)	1	n/a	3436 US$ per death averted	WHO Bulletin
4	Cairncross and Valdmanis (2006)	Global	Basic sanitation (hypothetical)	All ages	Not described?	36% median reduction (of Esrey and others' (1991)	5	Not described	270 US$ per DALY for construction and promotion; 11.15 US$ per DALY for promotion only	Disease Control Priorities in Developing Countries

	Authors	Country	Intervention	Age group	Coverage increase	Effect	Time horizon	Discount rate	Results	Source
5	Haller et al (2007)	Global	Hypothetical (improved WS&S) -combined	All ages	98%	32% reduction (improved sanitation) Fewtrell et al. (2005)	20	3%	20$ per DALY in AFRO D, 24US$ in AFRO E	Journal of Water and Health
6	Winara et al. (2011)	Indonesia	6 options including pit latrine	All ages	100% improved sanitation (ideal and actual)	36% relative reduction in diarrhea; and other diseases helminths, hepatitis A and E, trachoma, scabies, malnutrition and diseases related to malnutrition (malaria, acute lower respiratory infection, Measles)	5	8%	2,553$ per 1 DALY (from shared latrine to private septic tank in Tangerang district)	World Bank

	Authors	Country	Intervention	Age group	Coverage increase	Effect	Time horizon	Discount rate	Results	Source
7	Rodriguez et al. (2011)	The Philippines	5 options including pit latrine	All ages	100% improved sanitation (ideal and actual)	36% relative reduction in diarrhea; Other diseases (helminths and diseases related to malnutrition. malaria, acute lower respiratory infection, measles, etc.)	1 for dry pit; 20 for others	8%	2820US$ per 1 DALY	World Bank
8	Chuan et al (2012)	China	4 options including pit latrines	All ages	100% improved sanitation (ideal and actual)	36% reduction in diarrhea (basic sanitation alone)	10 years for pit latrine	8%	254.5 US$ per 1 DALY	World Bank
9	Anh et al. (2012)	Vietnam	5 options including flush to pit	All ages	100% improved sanitation (ideal and actual)	36% reduction in diarrhea (basic sanitation alone)	7 years For rural wet pit latrine	8%	331US$ per 1 DALY (pit latrine)	World Bank
10	Heng et al (2012)	Cambodia	3 options including pit latrine	All ages	100% improved sanitation	36% reduction in diarrhea (basic sanitation alone)	1 for CLTS dry pit; 3 for concrete ring	8%	1543US$ per 1 DALY	World Bank

	Authors	Country	Intervention	Age group	Coverage increase	Effect	Time horizon	Discount rate	Results	Source
					(ideal and actual)	(regardless of coverage?)	dry pit; 8 for rural wet pit		(pit latrine, Plan International)	
11	Spears (2013)	India	TSC	Infants (deaths)	-	Averting 4 infant deaths per 1000 live births	10 years (10-20)	10%	Average cost: (35$ for saving a life year)	India Policy Forum
12	Woode et al (2018)	Ghana	CLTS	Not described	Adoption rate is assumed	Improved hygiene behavior including 8latrine use	Not described	Not described	Improved latrine behavior	Heliyon
13	Jenkins et al (2018)	Nigeria	Sanitation improvement (USAID) Establishing and encouraging use of sanitation platform	All ages	6%	34% reduction in diarrhea	10 years (useful life of SanPlat is 3 years)	3%	18.53US$ per DALY averted	USAID
14	Crocker et al (2021)	Ethiopia & Ghana	CLTS	N/A	-	N/A latrine ownership; stopping open defecation	N/A	N/A	Coverage effect	International Journal of Hygiene and Environmental Health

	Authors	Country	Intervention	Age group	Coverage increase	Effect	Time horizon	Discount rate	Results	Source
15	Trimmer et al. (2022)	Ghana	CLTS+subsidy vs CLTS alone	N/A	-	Stopping open defecation/ Upgrading to a durable toilet	N/A	N/A	Coverage effect	Environmental Health Perspectives

2.3. Need for additional research

I reviewed 13 RCTs that assessed the effect of community-based sanitation interventions on child diarrhea. Out of the 13 trials, 10 found no discernible effect of improved sanitation on period prevalence of child diarrhea. The overall impact of sanitation interventions on diarrhea, based on meta-analysis, was minimal. This lack of effect could be partially attributed to inadequate latrine coverage or usage. A previous study suggested that a low level of open defecation or a higher level of latrine access or usage in the control group could be another contributing factor (Arnold et al., 2018). Food contamination or exposure to animal waste has also been previously identified as a significant cause of diarrheal infection (Toure et al., 2013; Islam et al., 2013; Zambrano et al., 2014; Conan et al., 2017). Beyond these existing arguments, insufficient coverage or usage of quality latrines may be another key reason for the negligible effects. Current studies indicate the need for additional research to explore the effect of sanitation interventions, as well as studies to investigate the chain of results from sanitation interventions to the reduction of child diarrhea.

Randomized controlled trials (RCTs) are the acknowledged standard in evaluating effectiveness and are recognized as the best method for generating evidence (Smith, 2024). Random allocation of study subjects ensures an even distribution of confounding factors between intervention and control groups, minimizing bias in assessing the effects of an intervention. However, there is evidence that randomization or RCT quality is sometimes subpar in certain contexts particularly when randomization is not conducted correctly (Koletsi et al, 2012). Bondemark and Ruf (2015) explained that in some cases the randomization and assignment protocol are not properly assessed by an independent researcher. Other characteristics of RCTs include their expensive, time-consuming nature, and ethical concerns when the control group does not receive any intervention. In this regard, they have acknowledged that other types of well-designed studies could be alternatives to RCTs by providing valuable evidence.

If the objective of a study is to evaluate different interventions, it has been widely recommended to primarily perform a well-designed RCT as they generate the highest level of evidence by limiting many types of bias (Sackett et al., 1996). RCTs have sometimes been criticised for reducing but not eliminating bias (Sami et al., 2011) and for having their own flaws (Kaptchuk et al., 2001). Johnston (2002) argued that RCTs can provide the best evidence when randomization and double-blind procedures are assured.

Smith (2024) argues that cross-sectional studies, cohort studies and case control studies have the potential for a higher external validity than RCTs, but they have lower internal validity. Therefore, I suggest that future studies combine well-designed RCTs and non-RCTs.

The findings of this review highlight the importance of latrine quality. Upon examining the results chain from sanitation interventions to health outcomes, it appears that the minimal or non-existent effects may be partially attributed to the substandard quality of the “improved latrines” promoted in these interventions. Below, I discuss the importance of latrine quality in greater detail.

Another possible reason for the lack of effect may be related to the methods used to identify cases of diarrhea or its seasonal variations. Many of the trials depended on parental reporting, which can be biased. Additionally, the frequency of measurements was limited to once or only a few times, so it is possible that effects were not detected during a season when diarrhea prevalence was relatively low, leading to low study power. I further discussed different methods of case identification and the pathogens responsible for diarrhea, especially in low- and middle-income countries.

2.4. Further areas of literature identified as important by the above review

Importance of latrine quality

When designing and implementing sanitation interventions, many factors must be considered, including the affordability and availability of latrine construction materials.

Many studies have investigated factors of latrine ownership and use in low- and middle-income countries including Ethiopia. Age, latrine sustainability and quality have been frequently suggested as key factors of latrine use in Ethiopia although the results of their association with latrine use were mixed (Alemu et al., 2017; Fry et al., 2015; Gebremedhin et al., 2018). Alemu et al. (2017) suggested that elderly people are less likely to use latrines due to their lack of capacity for adopting them, while Chambers et al. (2021) found that elderly people have a higher motivation to choose improved latrines because of their reduced mobility. The presence of school-aged children in the household was positively associated with latrine availability and use (Asnake et al., 2020, Ajemjoy et al., 2017, Anteneh et al., 2010; Yimam et al., 2014; Gedefaw et al., 2015; Debesay et al., 2013; Alemu et al., 2018). Households with female head were less likely to have a household latrine (Novotny et al., 2018; Tmane et al., 2021; Ross et al., 2011; Ajemjoy et al., 2017). Some of the reasons were their lack of capacity to adopt toilets, perceived inconvenience and fear of latrine use, and responsibility for small children (Tamene et al., 2021, Ajemjoy et al., 2017; Temesgen et al., 2021). Social-cultural norms and peer pressure were also factors affecting household latrine uptake and use either positively or negatively (Tessema, 2017; Ajemjoy et al., 2017; Chambers et al., 2021; Koyra et al., 2017). For instance, it was unacceptable for a married women to share a household latrine with inlaws in Ethiopia (Tamene et al., 2021). Maintenance- or quality-related factors of latrine such as smell, uncleanliness and the presence of flies also affected latrine use (Novotný & Mamo, 2022). Other factors included the availability of materials and manpower for latrine construction and institutional support (Novotný & Mamo, 2022)

High construction costs for latrines have been identified as a primary reason many settings lack these facilities (Jenkins et al., 2007). When the expense of rebuilding latrines is prohibitive, individuals are more likely to return to open defecation practices (Thomas et al., 2014). Affordability is a crucial factor in facilitating progress up the sanitation ladder (Whaley et al., 2011). It has been found that ensuring easy and convenient access to necessary materials can enhance both the use and maintenance of latrines (Munkhondia et al., 2016). These materials should be locally available and affordable for the majority of rural households. Additionally, hardware for more advanced latrines should be accessible for those individuals who wish to upgrade their latrine facilities (Musyoki et al., 2010).

Durability is another crucial factor in promoting latrine use (Whaley et al., 2011; Cavill et al., 2015). Poor construction and substandard materials can discourage people from using latrines, leading to their abandonment (Cavill et al., 2015). If a latrine is prone to easy collapse, people may revert to open defecation (SNV, 2015).

When households have access to technical support, they are more likely to maintain their latrines (Tyndale-Biscoe et al., 2013; Thomas et al., 2014). Taking all these factors into account, a well-designed latrine should hygienically separate human excreta from human contact, while being simple enough for everyone in a community to construct, use, and repair. Numerous structural elements must be considered to ensure that latrines effectively disrupt the transmission of pathogens and are constantly used. According to the existing literature, the key elements of a good latrine include pit depth, a pit-hole cover, a slab, a wall, a roof, a door and a hand washing facility (Figure 4) (WHO, 2023; Nakagiri et al., 2016; Nyarko et al., 2016). These elements are considered crucial for a latrine to disrupt the transmission of faecal pathogens and promote latrine use.

Pit depth is a crucial factor in ensuring the quality of a latrine. If a pit latrine requires frequent emptying, it has been reported to lead to a return to open defecation, particularly when individuals cannot afford to rebuild or repair the latrine, or lack necessary knowledge or skills to construct one (Coffey et al., 2015; Shah et al., 2013). Therefore, the pit depth should be sufficient to alleviate concerns about the need for frequent emptying. Moreover, a shallow pit depth has been associated with the presence of flies and odor (Anteneh et al., 2010; Tefera et al., 2008). However, excessively deep pits can deter people from using a latrine due to the substantial resources required for its construction (Myers et al., 2016). Additionally, the pit depth should not be so great as to risk contaminating water table (Graham et al., 2013).

Deep pits that are infrequently emptied may have untended consequences. Many scholars have highlighted the paradox of pit latrines, which act as hotspots for pollutants and greenhouse gases, posing risks to human and environmental health instead of protecting it. For example, it has been shown that pit latrines serve as reservoirs for contaminants and human pathogens (Chidavaenzi et al., 2000; Adejuwon and Adeniyi, 2001; Banks et al., 2002; Dzwairo et al., 2006; Graham and Polizzotto, 2013; Templeton et al., 2015; Nyenje et al., 2013; Dzwairo, 2018; Capone et al., 2021) as well as sources of greenhouse gas emissions (GHGs), particularly methane, a potent contributor to climate change (Poudel et al., 2023; Reid et al., 2014; Kulak et al., 2017; Ryals et al., 2019; Shaw et al., 2021; Cheng et al., 2022; Johnson et al., 2022). Recent research has also shown that pit latrines harbor emerging contaminants such as microplastics, endocrine-disrupting chemicals, pharmaceuticals, and personal care products (Liao and Kannan, 2011; Pérez-Guevara et al., 2021; Sorensen et al., 2015; Branchet et al., 2019; Gani et al., 2021). Furthermore, some studies have linked pharmaceuticals found in groundwater systems to pit latrines (Sorensen et al., 2015; K'oreje et al., 2016; Branchet et al., 2019; Kairigo et al., 2020a, 2020b; Ngumba et al., 2020; Twinomucunguzi et al., 2022).

The global health community is working to improve sanitation in line with the Sustainable Development Goals (SDGs), which is expected to result in a significant increase in the number of pit latrines worldwide. The greenhouse gases emitted from pit latrines can contribute to climate change and environmental degradation. Many scholars caution against the paradox of pit latrines and advocate for seeking further advancements in latrine technology rather than dismissing the importance of improved latrines (Gwenzi W et al., 2023).

In certain areas, some individuals have reported avoiding the use of their latrines due to fears associated with the pit's depth (Dittmer et al., 2009). It has been reported that round-shape pits are safer, as they are less prone to collapsing (Tefera et al., 2008).

The most common point of contact with faeces is the slab, which needs to be easily cleanable. In certain regions, the ability to wash the slab was identified by individuals as a crucial feature of their ideal latrine (Tefera et al., 2008). Multiple studies conducted in Ethiopia have found a correlation between the cleanliness, and hygienic condition of a latrine and its frequency of use (Gebremedhin et al., 2018; Yimam et al., 2014). A large squat hole and an unstable floor were reported as reasons for not using latrines (Tefera et al., 2008). It is essential that the slab is adequately sealed to prevent flies from entering (Munkhondia et al., 2016).

A pit hole cover, or lid, is a crucial element of a well-constructed latrine. Studies have shown that a pit hole cover can prevent flies from entering and inhabiting the latrine, thereby reducing the risk of food or water contamination with excreta pathogens (Munkhondia et al., 2016; Debesay et al., 2015). In the Tigray region of Ethiopia, it was found that households equipped with a latrine featuring a pit hole cover were more likely to utilize the latrines than those without such a cover (Debesay et al., 2015).

Walls, doors and roofs are considered to be facilitating factors that encourage household members to use a latrine, especially women and girls (Yimam et al., 2014; Debesay et al., 2015; Kema et al., 2012). Roofs are presumed to provide protection from rainwater and sunlight, potentially encouraging latrine use throughout both the rainy and dry seasons. Walls serve to prevent animals from entering the latrine, thereby reducing the likelihood of animals coming into contact with human excreta (Nakagiri et al., 2015; Nakagiri et al., 2016).

The presence of flies has been linked to decreased latrine utilization (Munkhondia et al., 2016; Debesay et al., 2013). It is recommended that latrine be situated as a safe distance from water sources to prevent contamination. However, if latrines are located too far from the household compound, it may discourage use, especially during the night (Tefera et al., 2008). These factors should all be taken into account when planning the design of latrine structures.

A pit latrine can be a source of pollution to the subsurface, if the groundwater table is shallow (Smits & Sutton, 2012; Butterworth et al., 2013). To address this issue, it has been recommended to maintain vertical and horizontal distances between a latrine and the water table, as well as any nearby water sources. This distance is commonly referred to as 'the setback distance' (Nenninger et al., 2023).

Nenninger et al. (2023) have criticized that horizontal distances did not consider local conditions affecting the transport of pollutants from a latrine pit, and the existing guidelines were established several decades ago without rigorous evaluation. Approximately 15-50m distances have been recommended between a latrine and water source (Graham & Polizzotto, 2013; Lewis et al., 1982; Franceys et al., 1992; Sphere Project, 2011; Water Aid, 2011). For example, studies primarily cited for recommendations of 15 meters' setback distance were published more than three decades ago or even further back (Wagner & Lanoix, 1958; Lewis et al., 1982; Franceys et al., 1992). Three of these four documents (Wagner & Lanoix, 1958; Lewis et al., 1982; Franceys et al., 1992) recommend a horizontal setback distance of 15 m for placement of a latrine near a water source.

Nenninger et al. (2023) have pointed out that most of the guidelines recommending setback distances are based on a small number of field studies, most of which are outdated and investigated one particular pollutant instead of considering all of the pollutants. Specifically, out of the four fields studies, recommending distances of 25-50 meters, three were conducted more than 75 years ago (Nenninger et al., 2023). There are various factors affecting the transport of pollutants to water source including soil characteristics, and Nenninger et al. (2023) argued that current recommendations are over-simplified and not applicable in many contexts. A recent review suggested that most of the guidelines have primarily focused on horizontal distance instead of considering the depth of the water table except for one (Lewis et al., 1982) although the flow of contaminants from a latrine is mainly vertical rather than horizontal. More rigorous and updated studies are required to investigate acceptable vertical and horizontal setback distances (Nenninger et al., 2023).

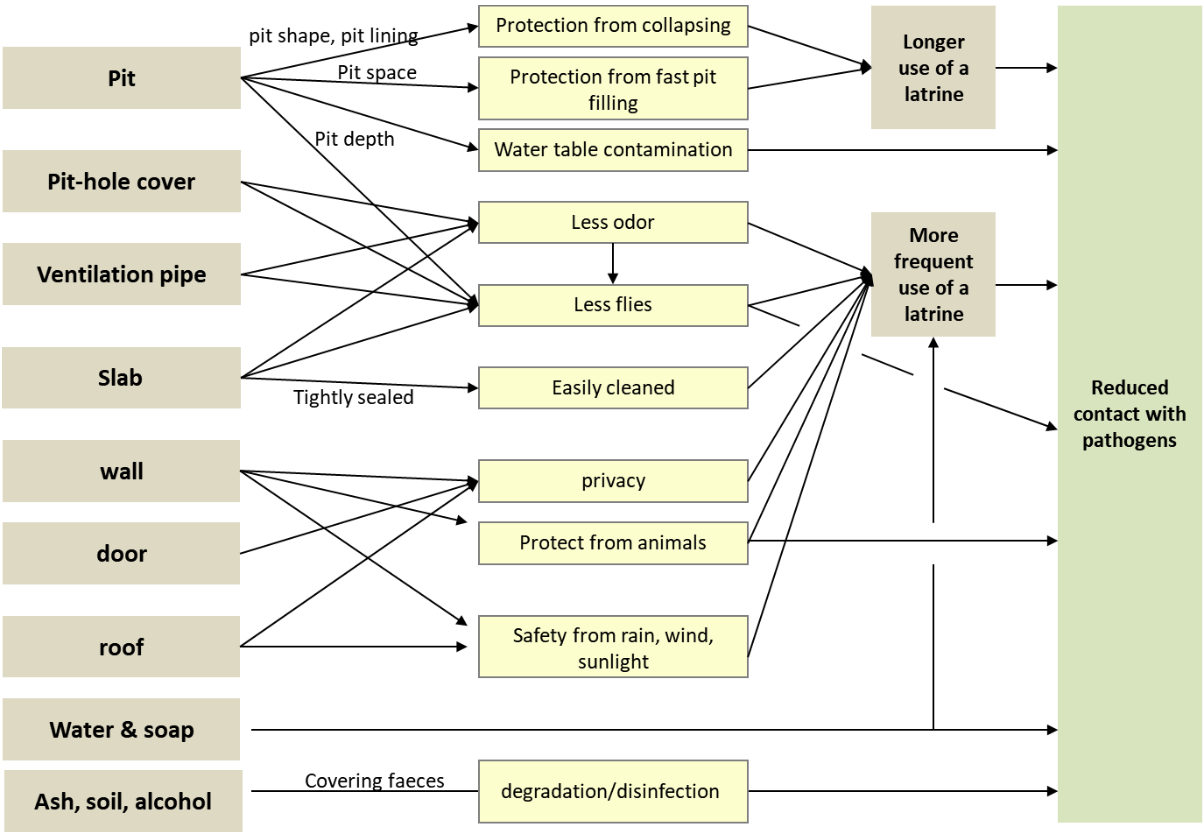


Figure 4. Latrine structure and its expected performance

Understanding the pathogens of diarrhea and the methods used for case ascertainment could provide us with insights into the quality of latrines or the potential reasons for the minimal effect of sanitation interventions on diarrhea. I will further elaborate on the pathogens of diarrea and its ascertainment methods.

Pathogens of diarrhea

It is important to understand types of diarrhea, its pathogens and reservoir in low- and middle-income countries because it will provide insight on the results chain between sanitation intervention and diarrhea reduction, and how to interrupt transmission of pathogens through latrine improvement. Diarrhea is categorized into three types: acute diarrhea, dysentery, and persistent diarrhea. Acute diarrhea, is typically defined as having three or more loose, watery stools within a 24-hour period. Dysentery is characterized by the presence of visible blood and mucus in diarrheal stools. Persistent diarrhea refers to diarrhea that lasts more than 14 days (WHO, 2023). Diarrhea can be caused by bacterial, viral, and parasitic pathogens. Historically, it was reported that the most common pathogens of diarrhea in low- and middle-income countries (LMICs) were enteric bacteria and parasites, while viral pathogens were the primary cause in high income countries (Alam et al., 2003; Amin et al., 2002; Cunliffe et al., 1998; Mustafa et al., 2000; Ono et al., 2001; Pang et al., 1999; Podewils et al., 2004). However, more recent studies have suggested that viral agents are also a major cause of diarrhea in LMICs (Kotloff et al., 2013; Platts-Mills et al., 2015; Platts-Mills et al., 2018). The primary mode of transmission for diarrheal agents is believed to be faecal-oral route, largely due to poor hygiene and sanitation in LMICs (Podewils et al., 2004). Poor hygiene and sanitation conditions also facilitate the spread of viral pathogens, but other transmission mechanisms are thought to exist for some viral pathogens (Santosham et al., 1985). For example, fomites and respiratory secretions have been suggested as possible transmission routes for rotavirus (de Wit et al., 2003).

A review of 73 studies conducted in 33 countries identified that bacterial pathogens collectively were the largest group of pathogens, with enterotoxigenic *Escherichia coli* (11%), *Campylobacter* (7%), and *Shigella* organisms (5%) being the most common. However, the most frequently identified individual agent was rotavirus (20%) (Black et al., 2002). A separate study in eight LMICs (Bangladesh, Brazil, India, Nepal, Peru, Pakistan, South Africa, Tanzania) determined that the primary pathogens of diarrhea from 2009-2012 were norovirus GII (5.2%), rotavirus (4.8%), *Campylobacter* spp (3.5%), astrovirus (2.7%), and *Cryptosporidium* spp (2.0%) (Platts-Mills et al., 2015). yet another study, conducted in Kenya, Mali, Mozambique, The Gambia, Bangladesh, India, and Pakistan, found that rotavirus, *Cryptosporidium*, enterotoxigenic *E. coli* producing heat-stable toxin (ST-ETEC), and *Shigella* were the most common causes of diarrhea (Kotloff et al., 2013). Both of these studies suggest that the pathogens responsible for diarrhea can vary substantially between countries and age groups.

Vibrio spp. and diarrheagenic *E. coli* are also important pathogens for diarrhea, although they are reported less frequently (Podewils et al., 2004). *Shigella* is the primary cause of bloody diarrhea, with a case-fatality rate reported to be around 10% in LMICs (Hosangadi et al., 2018; Kotloff et al., 1999; Podewils et al., 2004). Some bacteria also have animals as their reservoir. *Campylobacter* spp. and *Cryptosporidium* spp are the most frequently found pathogens in the stools of children in low-income countries (Kotloff et al., 2013; Platts-Mills et al., 2014; Coker et al., 2002). Poultry is another significant source of *Campylobacter* infections (Kaakoush et al., 2015; Komba et al., 2013; Padungton et al., 2003; Podewils et al., 2004). *Salmonella,* a bacterial pathogen, is prevalent in reptiles, fowl, and mammals (Besser et al., 2018; Faulder et al., 2017; Haselbeck et al., 2017). It has been reported that a risk factor for diarrheal infection is the presence of these animals in the cooking area in LMICs (Carr et al., 2001). Parasitic agents also cause diarrheal illness in children, with most episodes occurring in LMICs. The most commonly identified parasites causing acute diarrheal illness in children are *Giardia lamblia*, *Cryptosporidium parvum*, *Entamoeba histolytica*, and *Cyclospora cayetanesis.*

Cryptosporidium hominus and *C. parvum* are the two main Cryptosporidium species that cause the majority of human infections. The former is predominantly anthroponotic, while the latter is transmitted through a zoonotic cycle between humans and animals (Bouzid et al., 2013). Drinking contaminated water, contact with infected humans or animals, and eating contaminated food are the key risk factors for Cryptosporidium (Bouzid et al., 2013; Hunter & Thompson, 2005; Yoder & Beach, 2010).

In low- and middle-income countries, a significant risk factor for acquiring cryptosporidiosis is the lack of appropriate sanitation or open defecation (Bouzid et al., 2018). Direct transmission occurs through the faecal-oral route, including human-to-human or animal-to-human (Cama et al., 2008; Hunter & Thompson, 2005; Xiao & Feng, 2008).

Many pathogens replicate or survive in various environments. For example, pathogens can survive and multiply in water, decaying organic matter and on abiotic surfaces, creating habitats that facilitate transmission. The lifespan of pathogens in the environment varies greatly depending on their survival strategies. For instance, V. Cholerae forms biofilms to enhance their persistence and infectivity (Brown et al., 2012). Several environmental factors have been shown to impact the survival of pathogens, including temperature, humidity, salinity, and radiation (Levin & Eden, 1990). A study conducted in a marine environment found that an increase in seawater temperature promoted the spread of Vibro spp (Vezzulli, 2012).

Figure 2 illustrates the pathogens and risk factors of diarrhea, as wells as interventions against diarrhea.

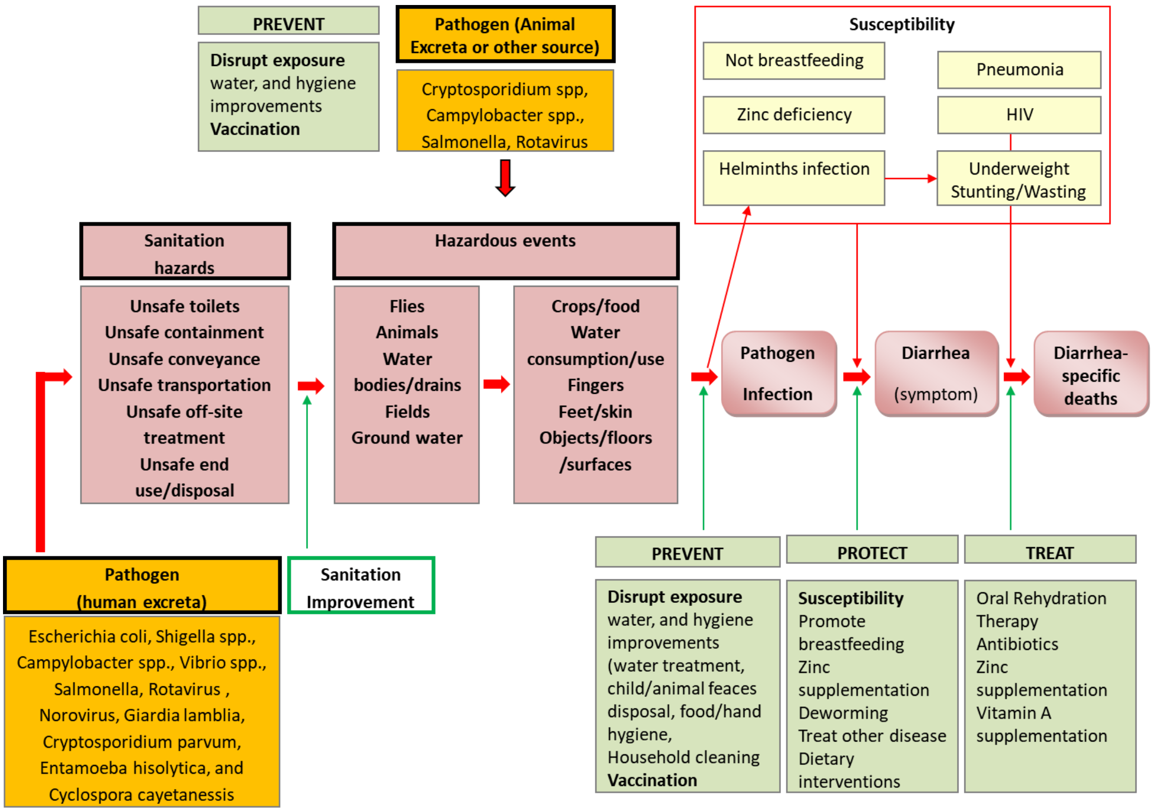


Figure 5. pathogens and risk factors of diarrhea, and interventions against diarrhea (adapted from Bhutta et al., 2013)

Diagnosis of diarrhea: case ascertainment

I would like to highlight the methods used to ascertain cases of diarrhea in existing studies. Diarrhea can be diagnosed either through clinical assessment or by parental report. Some studies use “sunken eyes, decreased skin turgor, IV hydration administered or prescribed, dysentery, or admission/recommendation for admission to the hospital” as criteria for clinically diagnosing moderate-to-severe diarrhea (Guerrant et al., 2008; Kotloff et al., 2012; Kotloff et al., 2013). In addition, molecular measurement of infections is performed to identify a specific diarrhea-causing pathogen and determine its burden (Kotloff et al., 2013; Platts-Mills et al., 2015). The severity of diarrheal episodes is evaluated based on the maximum number of loose stools within a 24-hour period, the number of days with vomiting, the presence of fever, dehydration, and the duration of diarrhea (Platts-Mills et al., 2015; Ruuska et al., 1990).

Most existing studies have relied on parental reports, which are susceptible to bias. Therefore, future research should incorporate molecular or clinical assessments alongside these parental reports.

Sanitation improvements are crucial in preventing the transmission of pathogens, as clearly illustrated in the “F-diagram” of disease transmission (Wagner et al., 1958) (Figure 6). Pathogens from human excreta can enter the environment, where they have the potential to replicate and remain infectious for a certain period. While the appropriate management and disposal of excreta are the most critical control measures to prevent the transmission of faecal-oral diseases, the transmission mechanisms of these pathogens through sanitation, drinking water, and hygiene are not independent, but rather interconnected (WHO, 2018). This is the primary reason why it is important to stress that people should be encouraged to adopt the use of improved latrines, rather than simply ceasing the practice of open defecation. Furthermore, even in the absence of human excreta, other sources such as animal faeces could potentially serve as sources of infection.

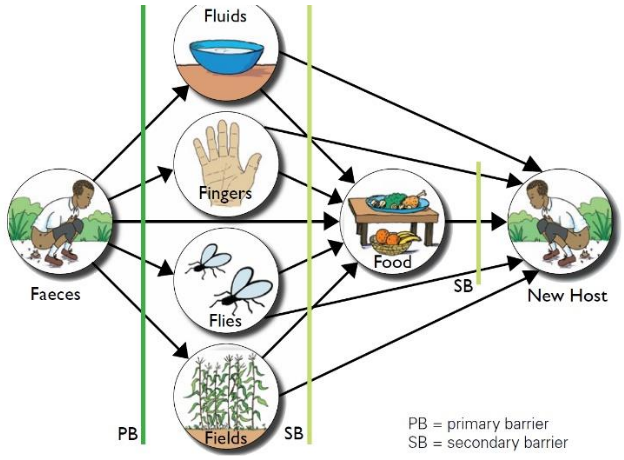


Figure 6. 5F diagram (Source: UNICEF Nutrition-WASH Toolkit, 2016; Wagner & Lanoix, 1958)

Research gaps

Future trials should address the following limitations observed in previous studies. Firstly, a precise operational definition of an improved latrine must be established before any intervention. Consequently, future research should investigate what constitute an acceptable latrine type by exploring the associations between improved or unimproved latrines and health outcomes, or intermediate outcomes of faecal-oral contamination. In particular, I would recommend further investigation in the relationship between latrine structure and the presence of feces on the latrine floor. One common characteristic in the two trials that showed an effect or a partial effect (Luby et al., 2018 & Cha et al., 2021) was a significant reduction in the presence of faeces on the latrine floor. This suggests that latrines without feces on the floor may be an indicator of a good latrine, potentially contributing to a reduction in diarrhea. Further research is needed to determine which specific components of latrine design could help prevent or eliminate feces on the latrine floor.

Secondly, future studies should limit the definition of ODF to “Total Sanitation”. Thirdly, to reduce the potential for bias, all aspects of a latrine should be meticulously measured, for instance, through photography, and latrine use should be directly monitored using objective indicators. Fourthly, the number of flies within a latrine, and the quantity of human faeces inside and outside the household compound should be concurrently counted to evaluate the effect of interventions on the intermediate outcomes of faecal-oral contamination. Fifthly, I suggest that researchers track the longitudinal prevalence and incidence of child diarrhea to assess its fluctuation over time. Lastly, sanitation intervention trials should include economic evaluations. Cost-benefit and cost-effectiveness studies of sanitation interventions should primarily utilize empirical datasets, rather than heavily relying on assumption-based parameter values.

Chapter 3. Study Protocol

The following chapter provides a comprehensive description of study protocol. This includes the study design, study settings, sampling and sample size, intervention and procedures, randomization and masking, measurement methods, operational definition of improved latrines. Additionally, the methods of statistical analysis, as well as the background and implications of this trial, are thoroughly explained.

RESEARCH PAPER COVER SHEET

Please note that a cover sheet must be completed for each research paper included within a thesis.

SECTION A-Student Details

Student ID Number	Lsh157351	**Title**	Dr.
First Name(s)	Seungman		
Surname/Family Name	Cha		
Thesis Title	Evaluation of a community-led total sanitation intervention in a rural area of the Southern Nations, Nationalities, and Peoples' Region, Ethiopia		
Primary Supervisor	Wolf Schmidt		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

SECTION B-Paper already published

Where was the work published?	Trials		
When was the work published?	18 April 2016		
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion.			
Have you retained the copyright for the work?*	No	Was the work subject to academic peer review?	Yes

If yes, please attach evidence of retention. If no, or if the work is being included in its published format, please attach evidence of permission from the copyright holder (publisher or other author) to include this work.

SECTION C-Prepared for publication, but not yet published

Where is the work intended to be published?	
Please list the paper’s authors in the intended authorship order:	
Stage of publication	

SECTION D-Multi-authored work

For multi-authored work, give details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	SJ and **SC** conceived the study and led the study design. **SC** and SJ drafted the manuscript. **SC** supervised the trial as a principal investigator.

SECTION E

Student Signature	
Date	**10-12-23**

Supervisor Signature	
Date	**27-12-23**

The effects of improved sanitation on diarrheal prevalence, incidence, and duration in children under five in the SNNPR State, Ethiopia: study protocol for a randomized controlled trial

• Sunghoon Jung, • Young-Ah Doh, • Dawit Belew Bizuneh, • Habtamu Beyene, • Jieun Seong, • Hyunjin Kwon, • Yongwhan Kim, • Girma Negussie Habteyes, • Yigrem Tefera • Seungman Cha

Abstract

Background

Diarrhea is one of the leading causes of death, killing 1.3 million in 2013 across the globe, of whom, 0.59 million were children under 5 years of age. Globally, about 1 billion people practice open defecation, and an estimated 2.4 billion people were living without improved sanitation facilities in 2015. Much of the previous research investigating the effect of improved sanitation has been based on observational studies. Recent studies have executed a cluster-randomized controlled trial to investigate the effect of improved sanitation. However, none of these recent studies achieved a sufficient level of latrine coverage. Without universal or at least a sufficient level of latrine coverage, a determination of the effect of improved latrines on the prevention of diarrheal disease is difficult. This cluster-randomized trial aims to explore the net effect of improved latrines on diarrheal prevalence and incidence in children under five and to investigate the effect on the diarrheal duration.

Method/design

A phase-in and factorial design will be used for the study. The intervention for improving latrines will be implemented in an intervention arm during the first phase, and the comparable intervention will be performed in the control arm during the second phase. During the second phase, a water pipe will be connected to the *gotts* (villages) in the intervention arm. After the second phase is completed, the control group will undergo the intervention of receiving a water pipe connection. For diarrheal prevalence, five rounds of surveying will be conducted at the household level. The first four rounds will be carried out in the first phase to explore the effect of improved latrines, and the last one, in the second phase to examine the combined effects of improved water and sanitation. For documentation of diarrheal incidence and duration, the mother or caregiver will record the diarrheal episodes of her youngest child on the "Sanitation Calendar" every day. Of 212 *gotts* in the project area, 48 *gotts* were selected for the trial, and 1200 households with a child under 5 will be registered for the intervention or control arm. Informed consent from 1200 households will be obtained from the mother or caregiver in written form.

Discussion

To our knowledge, this is the second study to assess the effects of improved latrines on child diarrheal reduction through the application of Community-Led Total Sanitation.

Trial registration

Current Controlled Trials, ISRCTN82492848

Background

Diarrhea is one of the leading causes of death, killing 1.3 million in 2013, of whom 0.59 million were children under 5 years of age [1]. This preventable and curable disease accounts for 11 % of child mortality [2]. The lack of improved sanitation is the most important contributing factor to diarrheal disease in many low-income countries [3]. During the Millennium Campaign period, sanitation coverage has not progressed as planned and remains a daunting challenge for the next campaign of the Sustainable Development Goals [4, 5]. Globally, approximately 1 billion people practice open defecation, and an estimated 2.4 billion people lived without improved sanitation facilities in 2015 [1]. Sub-Saharan Africa showed slower progress in sanitation coverage, reaching 31 % in 2015 from 24 % in 1990, whereas South Asia has increased coverage to 49 % from 22 % in the same period [1]. Inequality in coverage also exists between rural and urban areas. In contrast with 40 % of the urban population accessing improved sanitation in sub-Saharan countries, only 23 % of people in rural areas have access to improved sanitation [1]. Ethiopia shows a high child mortality rate, with 74.4 children out of 1,000 live births dying before they reached the age of five in 2013. Diarrheal disease accounts for 9 % of child mortality, ranking as the fourth most frequent cause of child deaths [6]. In Ethiopia, 72 % of the people are living without improved sanitation facilities [7]. Much of the previous research investigating the effect of improved sanitation has been based on observational studies [8–11]. According to the results of a recent systematic review [12], few studies have involved a cluster-randomized controlled trial on sanitation intervention. Recently, several studies [13–15] have investigated the effect of improved sanitation, executing a cluster-randomized controlled trial. These studies did not demonstrate any protective effect of improved latrines against child diarrheal prevalence. However, none of the recent studies achieved universal or even a sufficient level of coverage required for fostering herd immunity. Without universal or at least a sufficient level of latrine coverage, the effect of improved latrines on the prevention of diarrheal disease is difficult to determine. Furthermore, most of the recent studies employing rigorous methodology have been conducted in South Asia. Since a number of people are living without improved sanitation in sub-Saharan Africa, a strong need exists for further evidence of the effect of improved sanitation in rural sub-Saharan Africa.

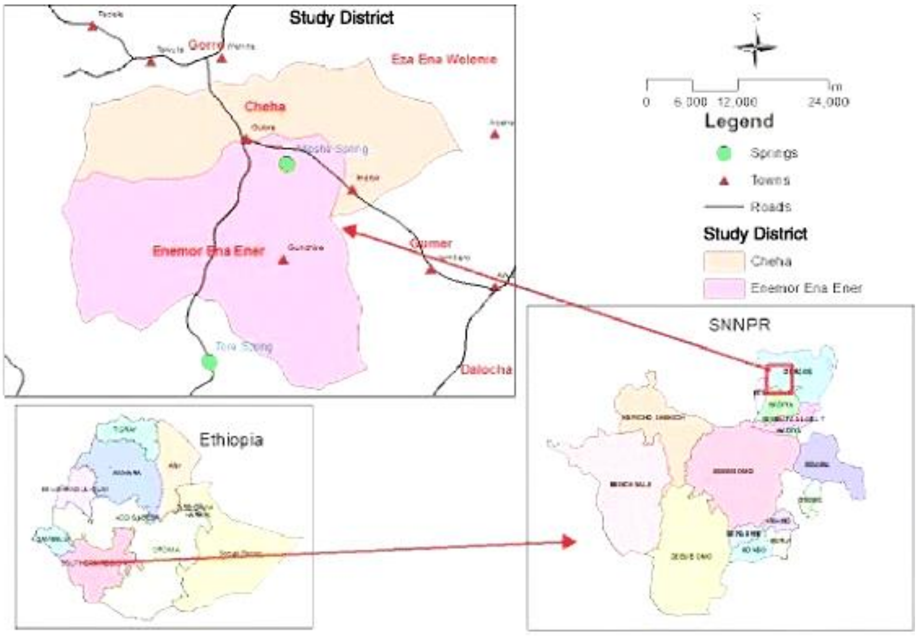
This study aims to explore the net effect of improved latrines on reducing diarrhea in children under five, particularly when latrine coverage reaches a certain threshold level. In addition, we aim to investigate the effect of improved latrines on the diarrheal duration of children by recording diarrheal incidence on a daily basis.

This study was designed as a cluster-randomized trial in the Southern Nations, Nationalities, and Peoples' Region (the SNNPR State), Ethiopia, with the aim of finding evidence of the effect of improved latrines on diarrheal diseases in children under five. To our knowledge, this is the second study to assess the effects of improved latrines on child diarrheal reduction through the application of Community-Led Total Sanitation.

Methods/design

Study setting

The Cheha District and Enemore Ena Ener District, the target area of the project, are located 185 km southwest of Addis Ababa. According to the District Statistics Office, the total population of each district was 133,233 and 204,937, respectively, in 2014. Both districts are predominantly rural areas with 90 % of the entire land used for farming, and the major sources of income are crop production and livestock farming. Coffee, *chat*, and oil seeds are among the major cash crops in both districts, and plantations of eucalyptus trees for income are also very common. The dominant ethnic group, which accounts for more than 80 % of the population in the area, is the Gurage people, after which the administrative zone of the area is named (Gurage Zone). Of the population in the area, 64 % are Muslim, whereas 33 % identified themselves as Ethiopian Orthodox Christian (Fig. 1).



1-1 Project area

1-2 Project area (Cheha district: yellow)and study area (dots)

1-3 Project area (Enemor Ena Ener district: yellow)and study area (dots)

Fig. 1. Project area and study area

Study design

The study was approved by the National Research Ethics Review Committee under the Ministry of Science and Technology, Federal Democratic Republic of Ethiopia (NRERC

3.10/032/2015; July 29, 2015) and was registered as an ISRCT on March 13, 2015 (ISRCTN82492848).

In the study, a *gott*, the Amharic word for village, was taken as the randomization unit because we expected that improved latrines could impact diarrheal transmission across households within a *gott*, where people interact with one another most closely. All the interventions related to latrine improvement will be performed at each *gott* level.

A phase-in and factorial design will be used for the study. The intervention for improving latrines will be implemented in the intervention arm during the first phase, and the comparable intervention will be performed in the control arm during the second phase. During the second phase, a water pipe will be connected to the *gotts* in the intervention arm. After the second phase is completed, the control group will receive the intervention of a water pipe connection. With the design, we will investigate not only the effect of improved sanitation but also the combined effects of improved water and sanitation interventions.

A preliminary survey was carried out to develop this water, sanitation, and hygiene (WaSH) project intervention design in March to May 2013. Water pipes will be connected to 212 *gotts*, of which, 48 gotts were selected as the study area of the trial. In the intervention *gotts*, the procedures of the Community-Led Total Sanitation including pre-triggering, triggering, and follow-up will be carried out for latrine improvement beginning in November 2015 and will continue to October 2016.

Primary endpoint

The primary endpoint of the study is diarrheal prevalence in children under 5 years of age. We will use 7-day prevalence of reported diarrhea in the household, which will be based on parental reports. The survey will be conducted five times at the household level: the first four rounds will be carried out in the first phase to explore the effect of improved latrines, and the last one, in the second phase to assess the combined effects of improved water and sanitation.

In addition to diarrheal prevalence, we will measure diarrheal incidence and diarrheal duration. For documentation of diarrheal incidence and duration, we will have the mother or caregiver record the diarrheal episodes of her youngest child on a “Sanitation Calendar” (Amharic language: *Yenezehenna Gize Saleda*) on a daily basis (Fig. 2).

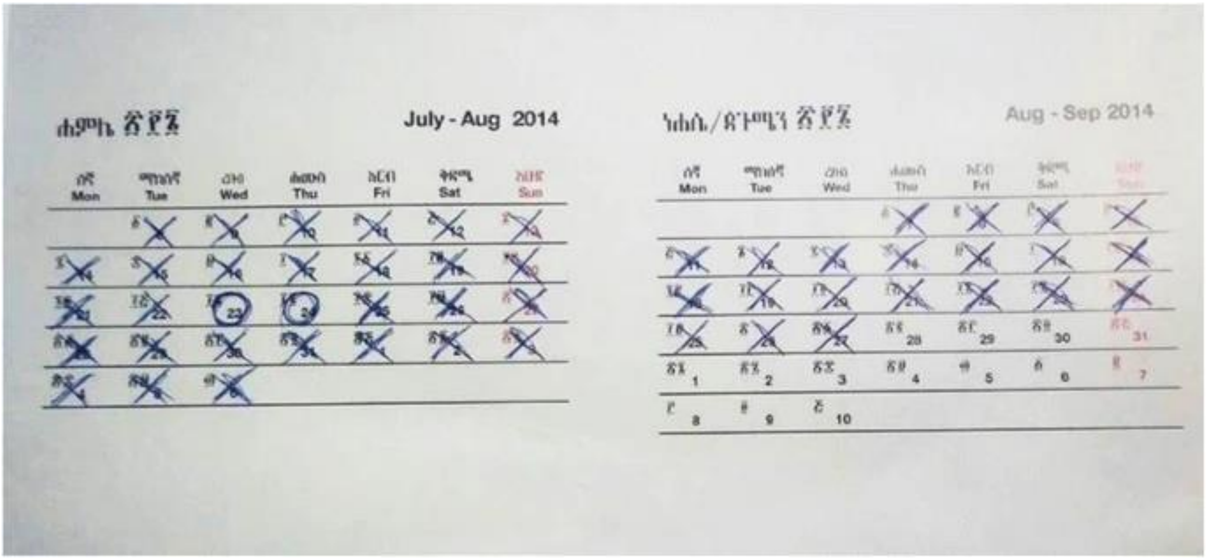


Fig. 2. Sanitation calendar

Sample size calculation

Period prevalence of diarrhea

The prevalence of diarrhea was estimated to be 24 % on the basis of a preliminary survey in the SNNPR State, and we expect that our intervention will lead to a 30 % relative reduction on the basis of systematic review results [16]. Assuming a design effect of 2.14 and a coefficient of variation of 0.15, an 80 % study power resulted in 48 clusters (48 gotts) and 600 children per arm. We employed a two-stage cluster-sampling method for the study. Among the 212 *gotts* targeted by the project for the water pipe connection, 48 gotts were chosen as primary sampling units.

Incidence density of diarrhea in terms of child-weeks

The expected value of the incidence density, E (s^2), is given by

$$\mathrm{E}\left(\mathrm{s}^2\right) = \lambda \mathrm{Av}\left(1/\mathrm{y_j}\right) + \sigma^2{}_{\mathrm{c}} = \lambda \mathrm{Av}\left(1/\mathrm{y_j}\right) + \mathrm{k}^2\lambda^2,$$

where λ is the true mean rate, y_j corresponds to the child-weeks of follow-up in the $_j$th cluster, Av() indicates the mean overall clusters, σ_c^2 is the between-cluster variance of the true rates, and k is the coefficient of variation of those rates [17]. Based on the preliminary survey, the overall diarrheal rate in the 48 gotts was 0.18 (or 18 cases per 100 child-weeks). The empirical standard deviation of the observed diarrhea rates was 0.092189, and the average of the reciprocal child-weeks per neighborhood was 0.001667. Therefore, k was estimated as

$$\sigma^2 = 0.092189^2 - 0.18 \times 0.001667 = 0.008199,$$

$$\text{and therefore, } k = \sqrt{(0.008199/0.18)} = 0.213422.$$

We assumed that the diarrhea rate in the control gotts remained constant at $\lambda_0 = 0.18$, and we required 90 % power ($z_\beta = 1.28$) if the intervention reduced the diarrhea rate by 21 %. Assuming 600 child-weeks of observation (24 weeks of follow-up for 25 children) in each gott, the number of neighborhoods required for each treatment group is given by $c = 1 + (1.96 + 0.28)^2[(0.18 + 0.1422)/600 + 0.213422^2(0.18^2 + 0.1422^2)]/(0.18 - 0.1422)^2 = 22.55$.

Household sampling methods

A list of households with children under 5 years of age was established by four supervisors in each *gott* before the baseline survey. Supervisors required 8 days to produce a complete household list for all 48 gotts. Using SPSS 21 Statistics software, the survey team leader randomly sampled 25 households from each gott. Enumerators will recruit the youngest child under five from each household, from the fifth week of October through the second week of November 2015. If the mother or a household caregiver is absent at the time of the recruitment visit, the enumerator will revisit the same household two more times. If the mother or caregiver refused to be registered, a neighboring household with a child under 5 was visited to replace the household (Fig. 3).

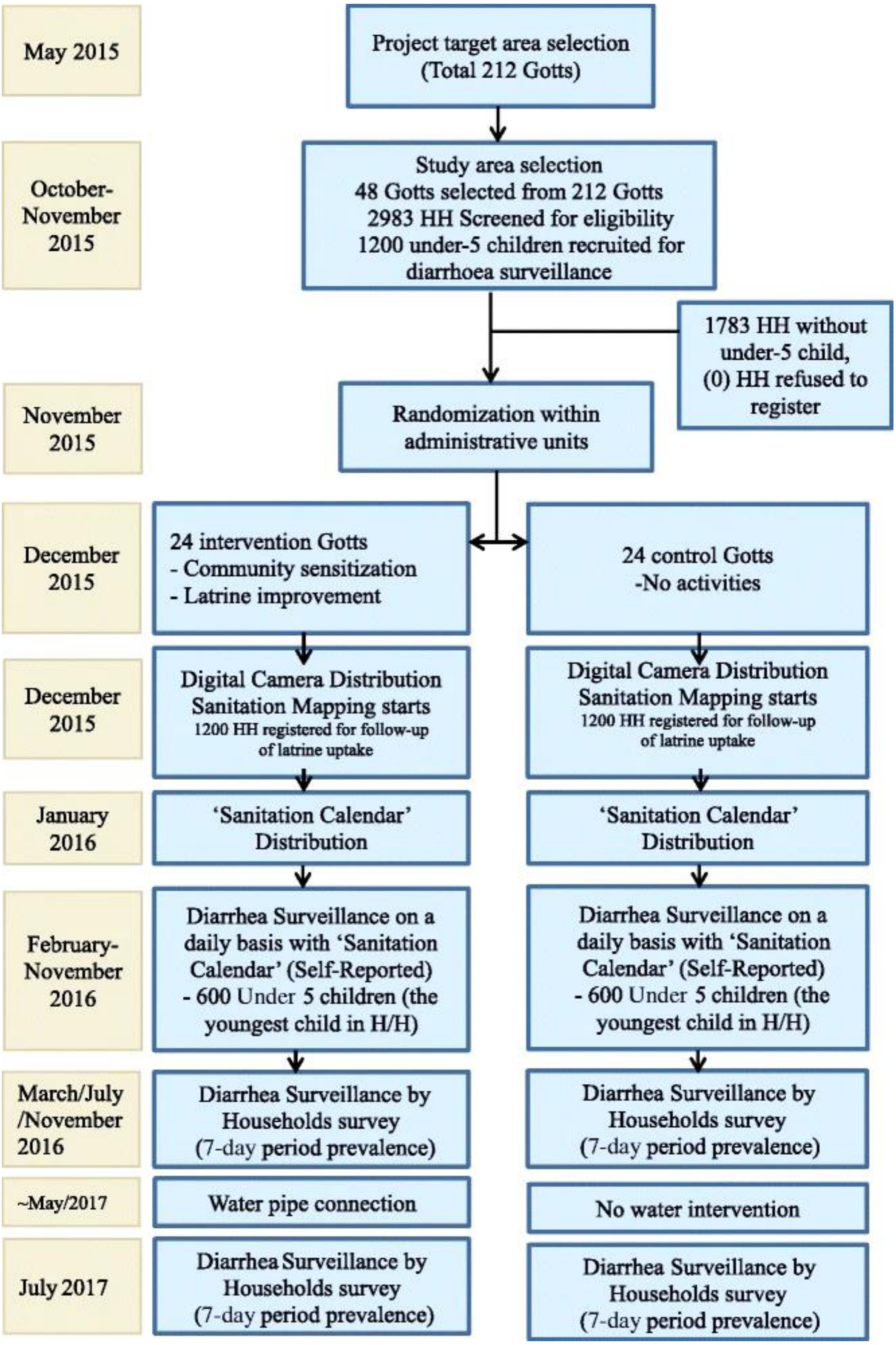


Fig. 3. Flow diagram

Eligibility criteria and randomization

The criteria for gott-level eligibility were (1) the lowest coverage of improved sanitation, (2) the lowest coverage of improved water, (3) similar population size, (4) similar distance from the main road, (5) road accessibility, (6) sufficient number of households with an under-five child, (7) sufficient distance between study *gotts* to prevent contamination, and (8) no other WaSH projects are to be implemented during the study period.

To select eligible *gotts* for the study, we used the data from the preliminary survey and from the special survey for the water pipe connection. The preliminary survey was carried out in March through May 2013, and the special survey was conducted in August 2014 in 212 *gotts* across the two target districts.

The criteria for household level eligibility are (1) having a child under 60 months at the time of recruitment and (2) agreeing to register with informed consent.

The age of a child will be verified with an immunization card, which shows the birth date of the child. Informed consent from 1200 households registered will be obtained from the mother or caregiver in written form. A structured questionnaire will be administered regarding water, sanitation, and hygiene, including demographics and socioeconomic characteristics.

The *gotts* in the study area were stratified according to the administrative unit (*kebelle*, in Amharic, which is the administrative unit above the *gott*) so that every *kebelle* contained both intervention and control gotts. By doing so, we were able to increase the balance between the intervention and control arms because *gotts* in the same *kebelle* were expected to have more common characteristics in terms of economic status, tribe, religion, geographical conditions such as altitude, and WaSH-related behaviors. In addition, local government officials of the study area also requested that we allocate the same number of study *gotts* in each *kebelle* to prevent any conflicts of interest among the *kebelles*. To avoid contamination, we allocated a buffer zone between the intervention and control gotts in every *kebelle*. A closed cohort design will be employed for the study. Any new baby born during the longitudinal survey period will not enrolled for the study.

Intervention

In alignment with the National Hygiene and Sanitation Strategic Action Plan (2011-2015) [18], the Ethiopian Government's policy on sanitation, we applied the principles of Community-Led Total Sanitation (CLTS) for the study. The Gurage zonal office, the SNNPR State of Ethiopia, and the Re-shaping Development Institute (ReDI) are implementing the project. The project is funded by the Korea International Cooperation Agency (KOICA).

CLTS implementation

In accordance with the Ethiopian government's guidelines on this issue, the primary approach for implementation of latrine improvement and hygiene promotion adopted for this program is Community-Led Total Sanitation. Of 48 *gotts* selected in the project area, 24 *gotts* in the project area were selected (intervention arm) and will receive the CLTS intervention and undergo intensive follow-up throughout the first phase of the implementation period (approximately 12 months) for latrine improvement. As the first step of CLTS, a team of trained CLTS facilitators will conduct the triggering process in each of these 24 *gotts*. During this triggering process, facilitators will use participatory tools, such as transect walk, sanitation mapping, and calculating feces deposition to help community members realize the health effects of open defecation practices in their *gotts*. In the process, basic human emotions, including shame and disgust, will be aroused among the *gott* members regarding their own defecation practices. Successfully implemented, the triggering activities of the CLTS, which normally take half a day for each *gott*, can be a very effective tool to motivate community members to stop open defecation and to eventually construct and use latrines of their own accord.

In accordance with the core principle of CLTS, no material or financial subsidies will be provided for the construction of individual household latrines. Household members will take responsibility for the whole process of latrine construction including (1) pit-hole digging; (2) constructing a slab and pit-hole cover; (3) constructing the walls, door, and roof; and (4) installing hand-washing facilities. The community member's labor cost for construction of a latrine is expected to be approximately US$5.95 (125 Ethiopian birr as of October 23, 2015) per household. Ten full days of labor are estimated to be required for the construction of an improved latrine per household if two adults were to work together for the procurement of materials (wood, thatch, stone, and so on) and construction of the latrines.

We produced an operational definition for an improved latrine for the project as having (1) a pit-hole with at least 2.5 m of depth, (2) a slab, (3) a pit-hole cover, (4) a superstructure, (5) a door, (6) a roof, and (7) hand-washing facilities (Fig. 4). We did not prescribe the materials for any component of the latrine, expecting those to be locally available and affordable materials to ensure sustainability. If a latrine lacks any of the elements specified above, it would not qualify as an improved latrine.

Fig. 4. Model latrine

WaSH promoter

At the beginning of the implementation period, one (1) villager from each intervention *gott* will be designated and trained as a WaSH promoter to carry out post-triggering or follow-up CLTS activities in his/her *gott*. To ensure the coverage and quality construction of the latrines in each *gott*, and also the long-term utilization of the latrines to be built, these WaSH promoters will employ a combination of various approaches including technical advice on latrine construction, collective awareness-raising, and household visits.

For this purpose, during the initial phase of implementation, WaSH promoters in each *gott* will be trained on key issues regarding latrine construction and use. Once trained, these WaSH promoters are to be the leading agents to promote and follow-up on the latrine improvement and sanitation-related behavior change in the promoter's respective Gott. More specifically, WaSH promoters will be responsible for activities including household visits, community conversations, technical advice on latrine design, organization of and participation in monthly review meetings with stakeholders, and so on. In line with the Ethiopian government's CLTS Guideline, no material subsidies will be provided for the construction of individual household latrines. Instead, most of the resources, both human and financial, of the project are to be allocated for activities aimed at promotion of latrine construction and use, as well as the sanitation behavior change of the community.

Water intervention

When the CLTS intervention is completed, the second phase starts, during which water pipes will be connected to 24 *gotts* from one single spring on a mountain in each district. A spring capable of supplying sufficient water across the district is already identified and designing a water-pipe connection plan is under process. Immediately after the final round of the survey is finished, the water pipe will be connected to all the other 24 gotts.

Sanitation mapping

To assess the progress of latrine uptake, a sanitation map will be drawn and updated on a monthly basis. In addition to the households recruited for the longitudinal household survey, all the households in the 48 *gotts* will be registered to assess the real-time latrine status. All the households in the 48 *gotts* will be endowed with an identity number and marked with red, yellow, or green. If a household completes construction of an improved latrine, the WaSH promoter will mark that household in green on the sanitation map. If the latrine is under construction, that household will be marked in yellow. If the uptake of an improved latrine does not occur, the household will be marked in red on the sanitation map. Each WaSH promoter will present the sanitation map for his/her *gott* during a monthly review meeting of WaSH promoters, which is intended to stimulate healthy competition between the *gotts*. A system of evaluation and reward at the gott level is established, and this system is expected to create peer-pressure within the *gott*. WaSH promoters will educate *gott* residents on the herd immunity effects [19] of improved latrines and the importance of universal or sufficient coverage of improved latrines. If a gott reaches 80 % improved latrine coverage, it will be certified as a "healthy *gott*" by the local government and will be rewarded by the project team. Material rewards will be given to both WaSH promoters individually and to those *gotts* collectively that show fast progress in improved latrine uptake.

Scoring latrine improvement status by household

For the assessment of improved latrine coverage in each *gott*, only the households with improved latrines will be counted. Households not practicing open defecation, but using communal or neighbor's latrines will not be counted in the latrine coverage assessment. To avoid subjectivity of WaSH promoters in categorizing the real-time status of latrine uptake, photos will be taken of a latrine by WaSH promoters and will be assessed and scored by supervisors and the team leader.

Direct observation will be made, especially of the latrine construction, utilization, and open defecation status. As for the latrine status, we will not only observe the presence of latrines but will also assess the latrine type for categorization by each element (e.g., pit more than 2.5 m deep, slab, pit-hole cover, superstructure/wall, roof, door, and hand-washing facility within 3 m of the latrine). To evaluate latrine utilization, odor, a spider web at the entrance, fresh feces, and a worn path to the latrine will be observed. To evaluate for ongoing open defecation, the presence of human feces around the household compound and in the *gott* will be observed.

In addition, to avoid measurement errors, 3-m-long sticks marked every 50 cm will be provided to WaSH promoters to measure the pit-hole depth. The presence of wet feces around the pit-hole and a spider-web at the entrance, and a worn path to the latrine will be observed to assess latrine utilization.

Health outcome assessment with a sanitation calendar

We distributed a sanitation calendar to all registered households beginning in December 2015 and asked mothers or caregivers to mark "O" or "X" depending on the presence of diarrheal disease of her youngest child every day over the 12-month period of longitudinal observation from December 2015 to November 2016. WaSH promoters have been monitoring the recording status of the sanitation calendar on a weekly basis and continue to educate and encourage mothers or caregivers to continue recording appropriately.

We devised an incentive mechanism to encourage the mothers or caregivers to record diarrheal episodes on the sanitation calendar properly by establishing a system where a well-maintained calendar can be used as a voucher. A well-recorded calendar, regardless of whether it contains Os or Xs will be exchanged with a gift-in-kind, probably sanitation-related materials such as soaps, nail clippers, toothpastes, or the like. WaSH promoters will take a photo of the sanitation calendar using a mobile phone and submit to a supervisor and the team leader. For the study, diarrhea is defined as three or more watery stools in 24 hours according to the WHO definition.

Intermediate outcomes

Sanitary survey

In each of the five rounds of the household survey (October 2015; March, July and November 2016; and July 2017), the presence of feces both inside and outside the household compound, and within the *gott* will be observed. The practices of child feces disposal will also be assessed by administering a structured questionnaire and observation.

Fly counts

Flies are known to be key vectors transmitting diarrheal pathogens from human feces. We will count the number of flies with glue traps. For all five rounds of the household survey, enumerators will be provided with glue traps of the same length per each household, and they will hang them around the pit-hole of a latrine, if any, before starting the interview. The enumerators will count the number of flies stuck on the glue traps after 30 minutes (Fig. 5).

Fig. 5. Fly trap

Data analysis

We will conduct intention-to-treat analysis to assess the effects of improved latrines on child diarrheal reduction. For the main independent variables, the incidence density, 7-day recall period prevalence, and diarrheal duration will be calculated. We will use generalized estimating equations to investigate the effect at the cluster level and a log-binomial model to calculate the incidence rate of diarrhea. Taking into consideration the between-cluster variation by assuming that there are cluster-level effects, we will use the random effects model. We will also conduct a multilevel analysis to explore the effects of coverage of a gott on the diarrheal incidence of an individual. (Coverage is defined as low if it is below 33 %; medium, 33–66 %; and high, above 66 %).

Discussion

This study seeks to assess the effects of improved sanitation on the health gains of children under 5 years of age and to explore the behavioral factors associated with latrine improvement. Several studies [13–15] have been conducted for a similar purpose with rigorous methodology in South Asian countries; however, those studies failed to reach universal or sufficient coverage of improved latrines. Furthermore, the results of recent randomized controlled trials cannot represent the effect of Community-Led Total Sanitation because they provided material or financial subsidies, although these were limited to the marginalized groups in the community. For example, a recent study [20] on improved sanitation, conducted in Bangladesh, revealed that subsidies could increase latrine ownership both in subsidized and unsubsidized households; however, those authors did not investigate the effects of the approaches for latrine improvement on scalability and sustainability, nor did they explore the effects on maintenance. For this study, we strictly applied the main principle of Community-Led Total Sanitation, paying close attention to the potential for scalability and sustainability. In the trial, community members will fully contribute to constructing their own household latrines, including digging a pit-hole; obtaining materials for the slab, pit-hole cover, walls, and roof; and completing installation.

For the study, a sanitation calendar has been devised to track child diarrhea more efficiently. We estimate the incidence density of diarrhea. With the sanitation calendar, the potential of recall bias [21] and respondent fatigue [22] due to frequent visits, which were the limitations of previous studies, are expected be reduced. Moreover, the sanitation calendar will help us to investigate the effects of improved sanitation on the duration of diarrheal diseases through the daily recording of diarrheal episodes. Assessing the effects of improved sanitation on the diarrheal duration has continuously been recommended as a future study topic in previous studies.

To ensure objectivity and avoid information bias, latrine improvement status will be photographed with tablet PCs or mobile phones provided to enumerators and WaSH promoters. Assessments of the latrine improvement status will be made by supervisors and team leaders, not by the enumerators or WaSH promoters, which helps avoid overestimating the coverage of improved latrines. Latrine improvement status will be scored on the basis of the photos taken. Using the scored results, the degree of the effects of the improved latrines will be explored according to the improved status.

To avoid contamination between the intervention and control *gotts* in the same *kebelle*, we excluded any neighboring *gotts* of either intervention or control *gotts* from selection, thus making those gotts serve as a buffer zone [23]. In this trial, keeping records on the sanitation calendar is one of the most important features. In order to encourage mothers or caregivers to record diarrheal incidence every day, WaSH promoters will visit registered households on a weekly basis. The sanitation calendar will be photographed on this visit, and the supervisors and team leader will randomly revisit some of the households to verify the results. The system of encouragement and verification will be strictly maintained, particularly during the first 2 months of the intervention period, so the mothers or caregivers of registered households will be familiar with recording cases of diarrhea. A community meeting will be convened every month, and the WaSH promoter will correct substantial errors related to sanitation calendar utilization. Our intervention is not to provide any financial nor material subsidy to community members. Rather, our intervention is to encourage community members to construct latrines for their own household members using locally available materials. We strictly comply with the key principles of Community-Led Total Sanitation (CLTS). Therefore, like all the previous studies, we have similar limitations such as the possibility of insufficient coverage. This study will provide sound evidence for determining the effects of improved latrines on the prevalence, incidence density, and duration of diarrheal disease of children under five.

Trial status

Trial recruitment had not commenced as of October 23, 2015.

Abbreviations

CLTSH: Community Led Total Sanitation and Hygiene

MDGs: Millennium Development Goals

NRERC: National Research Ethics Review Committee

SNNPR: Southern Nations, Nationalities, and Peoples' Region

WaSH: Water, Sanitation, and Hygiene.

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Competing interests

The authors declare that they have no competing interests.

Authors' contributions

SJ and SC conceived the study and led the study design. DBB, GNH, and YT provided expertise in the trial for the implementation of Community-Led Total Sanitation. YAD, HB, JS, HK, YK, and GNH participated in the design of the study, supervised the implementation of the trial, and edited the manuscript. SJ, HK, and GNH implemented the trial. SC and SJ drafted the manuscript. SC provided expertise on cluster-randomized trials. YAD, HK, DB, and JS edited the manuscript. All authors read and approved the final manuscript.

Chapter 4. Health effect of community-led total sanitation

The following research paper addresses research objective 1): assess whether a CLTS intervention reduced child diarrhea. The following research reports the effects of CLTS on child diarrhea, both in terms of period prevalence and longitudinal prevalence. Additionally, the study describes the intervention's effects on intermediate outcomes, including the presence and number of flies around the pit hole, faeces on the latrine floor, faeces inside and outside of the household compound, and latrine access and use.

RESEARCH PAPER COVER SHEET

Please note that a cover sheet must be completed for each research paper included within a thesis.

SECTION A-Student Details

Student ID Number	Lsh157351	**Title**	Dr.
First Name(s)	Seungman		
Surname/Family Name	Cha		
Thesis Title	Evaluation of a community-led total sanitation intervention in a rural area of the Southern Nations, Nationalities, and Peoples' Region, Ethiopia		
Primary Supervisor	Wolf Schmidt		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

SECTION B-Paper already published

Where was the work published?	American Journal of Tropical Medicine and Hygiene		
When was the work published?	24 June 2021		
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion.			
Have you retained the copyright for the work?*	No	Was the work subject to academic peer review?	Yes

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SECTION C-Prepared for publication, but not yet published

Where is the work intended to be published?	
Please list the paper's authors in the intended authorship order:	
Stage of publication	

SECTION D-Multi-authored work

For multi-authored work, give details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	**SC** analysed the data and drafted the manuscript under the guidance of W-PS. W-PS contributed importantly to the theoretical and practical considerations of the analysis and interpretation.

SECTION E

Student Signature	
Date	**10/12/23**

Supervisor Signature	
Date	**28/12/23**

Effect of a Community-led Total Sanitation Intervention on the Incidence and Prevalence of Diarrhea in Children in Rural Ethiopia: A Cluster-randomized Controlled Trial

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Abstract

We conducted a cluster-randomized trial in 48 rural villages of Ethiopia to assess the effect of community-led total sanitation (CLTS) on child diarrhea. Of them, 24 villages were randomly assigned to the intervention group, and the other 24 to the control group. A CLTS intervention was implemented by ReDI, a development NGO from January, 2016 through January, 2017.

Baseline data collection was conducted in October and November, 2015. At baseline, 906 children were recruited and followed up until January 2017. These 906 children were randomly selected among children in the 48 villages. For 7-day period prevalence of diarrhea, four rounds of household-based survey were conducted by independent data collectors at 3, 5, 9 and 10 months after the CLTS triggering. For incidence and longitudinal prevalence, daily diarrhea presence was recorded for 140 days using diary methods. The loss to follow-up was 95% for period prevalence and 93% for incidence and longitudinal prevalence. The incidence ratio and longitudinal prevalence ratio were 0.66 (95% confidence interval [CI]: 0.45-0.97, p=0.03) and 0.70 (95% CI: 0.52-0.95, p=0.02) after adjusting for clustering and stratification. The relative risk of period prevalence was 0.66 (95% CI: 0.45-0.98, p=0.04) at 3 months after the triggering. Improved latrine coverage increased from 0.0% at baseline to 35.0% at 10 months in the intervention villages, while it increased from 0.7% to 2.8% in the control villages. Adherence to the intervention was comparable with previous studies, and we thus suggest that the findings of this study are replicable.

Background

Diarrhea was the third-leading cause of disability-adjusted life-years (DALYs) among under-5 children in 2016.[1] Unsafe sanitation was reported to account for nearly half of an estimated 1.6 million diarrhea-specific deaths.[2,3]

The Sustainable Development Goals (SDGs) aim to ensure access to sanitation for all by 2030.[4] However, in 2017 an estimated 673 million people were still defecating in the open, and approximately 2 billion people lacked even basic sanitation facilities.[5] In Ethiopia, one of the top 10 countries with the highest burden of child death, diarrhea was the fourth leading cause of child death in 2015, accounting for 9% of child mortality.[6] Only 7% of Ethiopians were reported to live with access to basic or safely managed sanitation facilities in 2017.[5]

Recent systematic reviews have found improved sanitation to have a protective effect against diarrhea.[7,8] However, the quality of the evidence was scored as low or very low. Recent trials with robust designs have found little or no effect of improved sanitation on diarrhea with a few exceptions, and the ability of sanitation interventions to reduce diarrhea has therefore been called into question.[9-15]

Community-led total sanitation (CLTS) strategies emerged in Bangladesh in 2000 on the basis of lessons learnt that merely providing toilets or subsidies did not guarantee their use and often led to problems with sustainability.[16] With the principles of neither subsidizing latrines nor prescribing latrine models, CLTS focuses on collective behavior change to create open-defecation-free villages, enabling community people to become aware of their sanitation situation and triggering their desire to improve community-wide sanitation.[17] CLTS has been implemented in more than 60 countries, over 30 of which have adopted it as national policy, including Ethiopia.[18]

The Ethiopian government developed a community-led total sanitation and hygiene (CLTSH) policy in 2008.[19] In addition to the key principle of CLTS, CLTSH emphasizes the importance of improving hygienic practices. Kar, however, argues that a hygiene component, including handwashing, has been a key element of CLTS from its beginnings.[20] Like CLTS, CLTSH interventions include 1) preparation and planning (pre-triggering), 2) triggering, 3) post-triggering, and 4) verification, recognition, and scaling-up.

Despite the rise of CLTS, studies assessing its impact on sanitation coverage or child diarrhea are still scarce. Some trials have explored the effects of India's Total Sanitation Campaign on child health, in which subsidies were provided to some parts or all of the households in the intervention areas.[10,12,21] Other trials explored the effects of an intervention combining sanitation improvements or CLTS with other components such as sanitation marketing.[22-24] Trials have also investigated the effect of CLTS on latrine coverage, and/or compared the effect of different approaches.[25-27] The interventions analyzed in all these trials are broadly a sort of CLTS.[18,20] We aimed to evaluate the effect of CLTS on child diarrhea in a rural area of Ethiopia with strict application of the typical principle of CLTS (i.e., no subsidy provision). Two other important characteristics of this study are that we highlighted the importance of taking up improved latrines, not merely stopping open defecation, and that we measured the longitudinal prevalence and incidence of diarrhea as well as period prevalence. While typical CLTS principal focused on ending open defecation and on ladder of sanitation in low sanitation setting, this study highlights importance of having improved latrines that safely dispose excreta compared to use of open defecation and basic sanitation facilities.

Methods

Study design

We conducted a cluster-randomized trial in 48 rural villages (*gotts*) of the Cheha and the Enemor Ena Ener districts (*woreda*), in the Gurage zone of the SNNPR (Southern Nations, Nationalities, and Peoples' Region) state, Ethiopia between February 1, 2015 and February 23, 2017. A phase-in design was adopted, in which a CLTS intervention was implemented in 24 intervention villages in the first phase, and 24 control villages received comparable interventions during the second phase. The study was approved by the National Research Ethics Review Committee under the Ministry of Science and Technology, Federal Democratic Republic of Ethiopia (NRERC 3.10/032/2015; July 29, 2015) and the London School of Hygiene & Tropical Medicine (LSHTM Ethics Ref: 16260; February 22, 2019). This trial was registered as an International Standard Randomized Controlled Trial (ISRCTN82492848). The study protocol and rationale were published previously.[28] The analysis in this study adhered to the published study protocol.[28]

This trial was carried out under the umbrella of the Integrated Water and Sanitation project, funded by the Korean International Cooperation Agency (KOICA). The project comprised CLTS interventions and provision of piped water connections from springs to communities. All components related to water improvement were implemented after the CLTS trial was completed.

Study setting

The target areas of the project, the Cheha and Enemor Ena Ener districts, are located 185 km southwest of Addis Ababa. The populations of each district in 2014 were 133,233 and 204,937, respectively. Both districts are predominantly rural with 90% of the land used for farming, and the major sources of income were crop production and livestock farming. Coffee, khat, and oilseeds are among the major cash crops, and eucalyptus tree plantations for income are also common.[29] The Gurage ethnic group accounted for more than 80% of the population in the area, giving their name to the Gurage administrative zone. The majority of the population (64%) was Muslim, while 33% were Ethiopian Orthodox.[29]

The study areas had a specific context with regards to baseline sanitation coverage, with distinct differences from the general characteristics of low coverage shown in many previous trials.[10-13] The residents of the village were occasionally encouraged to build a latrine by health extension workers, particularly when visiting health centers or health posts. According to the baseline survey report, the coverage of a simple pit latrine was fairly high (73%) even before the project started, but many of the latrines were very unhygienic and poorly constructed.[30] This situation of fairly high coverage of simple pit latrines is not untypical for many other rural settings in sub-Saharan African countries including Kenya.[9] Therefore, we highlighted the importance of improved household latrines in this trial. The operational definition of an improved latrine is presented in the Procedures section. Open defecation based on direct observation was not especially common and the proportion of residents who disposed children's feces into the latrine was high (73%).[30] Handwashing practices were high before eating and before food preparation, but low after cleaning a child's buttocks and before feeding a child (for details, see Table 1).

Participants

A preliminary survey was conducted in August 2014 in 212 villages to assess water and sanitation coverage. We purposively selected 48 villages among the 212 villages of the two districts on the basis of the lowest level of water and sanitation coverage. The project team made field visits to check the accessibility of each village and excluded those that were hard to access with a vehicle. If two selected villages were located next to each other, we replaced one of the two with another village. The local authority requested that the same number of study villages should be allocated in every sub-district (*kebele*: administrative unit immediately above a village), and thus two villages were selected from each sub-district.

We listed all households with at least one under-5 child in all eligible villages and randomly selected 25 households from each village using SPSS version 21 software (IBM Corp., Armonk, NY, USA). The average population size and number of households per village were 351 and 73, respectively. There were 3,532 households in 48 villages, of which 1,129 (32%) had at least one under-5 child.

The caregivers of selected households were visited by enumerators to register. If a caregiver was absent, s/he was revisited two more times. If a caregiver was absent three consecutive times or more, or s/he refused to enroll in the study, we enrolled a neighboring household. The eligibility criteria for households were: (1) having a child under-60 months of age and (2) agreeing to participate in the study by providing written informed consent. Of the under-5 children in a household, we registered only the youngest child. The study participants were recruited between October 17 and November 27, 2015 in the Cheha and the Enemore districts.

Randomization and masking

To minimize the possibility of selection bias, we identified and recruited villages before randomization. Randomization was carried out in a community lottery ceremony by community leaders in each district. The allocation ratio was 1:1, with 24 villages each in the intervention and the control groups. If the two villages in a *kebele* happened to be allocated to the same arm during the lottery, we asked community leaders to do the lottery again until the two villages were finally assigned to different arms. Enumerators were not informed of the allocation to an intervention or control village; however, because some components of the intervention were visible, particularly latrine construction, they could not be masked to their intervention status.

Procedures

The CLTS intervention was carried out in accordance with the Ethiopian government policy from January 2016 through January 2017 (Supplementary material Text S1. Details on the intervention: selection criteria, demographic profiles and core tasks of CLTS promoters; benefits, training and supervision of CLTS promoters; selection and training of CLTS facilitators; and the dates of CLTS triggering). No financial or material subsidies were provided for constructing household latrines.

A co-founder of CLTSH trained CLTS facilitators. A team of trained CLTS facilitators comprising officials from the district health office, health professionals from health centers, and health extension workers visited the villages for pre-triggering to introduce themselves to, and build rapport with, village members, and to arrange the triggering schedule.

The facilitators carried out the triggering process in the 24 intervention villages, which took one day per village between February 11 and March 18, 2016.

The core components of the CLTS triggering process were applied with the aims of having community people realize the outcomes of open defecation practices to ignite shame or disgust.[16] Village members walked through the village from one side to the other and visited open defecation sites and different types of latrines along the way, experiencing the disgusting sights and smells (transect walk). Village members drew a map illustrating the sanitation situation in the village, locating defecation areas and their dwellings. They were asked to discuss where the dirtiest area was in their village (defecation areas mapping). They calculated the amount of feces they produced per day, per week, per month, and per year and how much they spent for treating diarrhea, dysentery, cholera, and other diseases due to open defecation (calculations of shit and medical expenses). They were offered a glass of water in which a hair that had touched some feces was dipped, and were informed that they could ingest each other's feces via the contaminated legs of a fly (the glass of water exercise).

At the outset of the intervention, one or two people from each intervention village were selected as CLTS promoters to conduct post-triggering activities. If the number of households in a village was 70 or more, two promoters were selected. Their main task was to encourage community members to build an improved latrine in their own way, using locally available materials, through community meetings and household visits. They were recommended to visit households every week to encourage latrine uptake. In order for a latrine to protect against the transmission of fecal matter, the following components were recommended: digging a pit-hole of 2 meters depth or more; installing a slab and a pit-hole cover; constructing a wall, door, and roof; and installing a hand-washing facility with soap. We defined an improved latrine in this study as having all of these components. This is a more stringent definition of an improved latrine than that of the Joint Monitoring Program (JMP) of WHO/UNICEF.[5]

In principle, CLTS does not prescribe toilet types. In many CLTS interventions, particularly where open defecation practices are very common, the usual approach is to convince people to build any toilet first and then continue to improve it, moving up along the sanitation ladder.[20] However, in this trial, community members in the study areas were encouraged to build improved latrines since the coverage of simple pit latrines was already high and open defecation was not especially common like many other rural settings in sub-Saharan African countries.[9] Materials for latrine components were not pre-specified because locally available and affordable materials could be diverse.

The CLTS facilitators and the project coordinators trained CLTS promoters for 4 days in April on how to build latrines, what latrine components are recommended, and the appropriate messages to deliver. After the training, the promoters promoted latrine improvement and followed up with the latrine construction progress. The Gurage zone office, the SNNPR state of Ethiopia, and the Re-shaping Development Institute (ReDI: a development NGO based in Korea) implemented the project.

Outcomes

The primary outcomes were the incidence, longitudinal prevalence, and 7-day period prevalence of child diarrhea. Duration of child diarrhea was also measured. We measured diarrhea only for the youngest child. The longitudinal prevalence and duration of child diarrhea were recorded by caregivers using the diary method. Diarrheal calendars were distributed to 906 households in May 2016 and caregivers were requested to mark O or X on each date of the calendar according to the presence or absence of a daily diarrheal episode. When distributing the calendar, the CLTS promoters educated the caregivers to record the daily presence of diarrhea in the registered child, who was the youngest under-5 child in their household at enrollment. The name of the youngest child was written on every page of the calendar. Having three or more stools in 24 hours was defined as diarrhea, and this was also indicated as a picture in the diarrheal calendar.

The CLTS promoters were trained to visit households weekly to check the recording status and encourage caregivers to keep recording correctly. CLTS promotors in the intervention villages also visited control villages to check and encourage caregivers to record daily diarrhea on the calendar in the same kebele. Apart from this encouragement to continue keeping diarrhea records, no other activities were conducted in the control villages. Data collection of daily diarrhea records were done by independent enumerators. The seven-day prevalence of diarrhea was recorded by independent data collectors in four rounds of household surveys based on the caregiver's recall in June, August, December 2016 and January 2017.

Immediately before the first round of the survey in June 2016, 36 enumerators were trained for 4 days by monitoring and evaluation specialists of the project team, district health officials, and an independent CLTS specialist, who was the master trainer of CLTS. For the survey, 45 mobile devices (Y520-U22, Huawei, Shenzhen, China) were purchased, and Akvo, a non-profit software development organization based in the Netherlands, was contracted to develop an app to collect data for this particular study and to train enumerators on how to use the technology. The secondary outcomes were defined as latrine coverage and latrine use. An intermediary outcome of fecal-oral contamination was also assessed by counting the number of feces inside and outside of the household compound, and assessing the number of flies (using a glue trap placed adjacent to the pit-hole for 30 minutes). Latrine construction status was directly observed by enumerators. Each component of the latrine structures (pit, slab, pit-hole cover, wall, roof, door, and hand-washing facility) were photographed by enumerators in every round of the survey. To assess whether the latrine was being used or not, enumerators checked for the presence of a worn path to the latrine, spider webs at the entrance, fresh feces inside the pit, and odor. In addition, direct observations were made of the presence of human feces inside and outside of the household compound.

Statistical analysis

The sample size for the trial was calculated as follows. First, the sample size for longitudinal diarrhea prevalence was calculated based on a preliminary survey in which the longitudinal prevalence was 18 days per 100 child-weeks and the coefficient of variation of the true longitudinal prevalence was 0.21. Assuming 80% study power, a ratio of longitudinal prevalence of 0.79 or smaller, and 24 weeks of follow-up for 25 children in each village, the calculation resulted in 23 clusters per each arm.[31]

Second, sample size calculations for 7-day diarrheal prevalence were based on a 30% relative reduction in the intervention group and a 24% diarrhea prevalence in the comparison group, which was estimated on the basis of a preliminary survey in 2015. Assuming a type I error (α) of 0.05, 80% study power (100%*(1-β)), 20% loss to follow-up, and a coefficient of variation of 0.15, the calculations resulted in 24 clusters for each arm, each with 25 children (design effect: 2.14).[22] We therefore selected a sample size of 600 households in each arm of 24 villages.

The assessment of the effects of community-led total sanitation on child diarrhea reduction was conducted on an intention-to-treat basis. We used a negative binomial regression random-effects model to assess the incidence ratio and the longitudinal prevalence ratio of diarrhea, accounting for intra-village and intra-individual correlations and adjusting for stratification by *kebele*. We used generalized estimating equations (GEE) with a log link and exchangeable correlation matrix to assess the relative risk (RR) of the 7-day period prevalence of child diarrhea and 95% confidence intervals (CIs) adjusting for clustering at the village level and stratification by *kebele*.

Longitudinal prevalence refers to the number of days with diarrhea. For the incidence of diarrhea, we used episodes at intervals of 2 or more days. Therefore, for this study, a period of 2 or more days without diarrhea was used to distinguish one episode from the next, as has been suggested to separate distinct episodes in areas where diarrhea is common.[32] Thus, two children with the same longitudinal prevalence (e.g. 7 days of diarrhea over 2 weeks) could have had a different diarrhea incidence. For example, one child could have had two episodes (e.g., for the first 2 days, he or she had diarrhea, followed by no diarrhea for the next 7 days, and then had diarrhea again for the following 5 days), while the other had only one episode (e.g., for the first 7 days, he or she had diarrhea every single day and then no diarrhea for the next 7 days). We illustrated the daily diarrheal cases in both the intervention and control groups for 140 days during the CLTS intervention. The first day of daily diarrhea records started on June 3, which was about 3 months after the CLTS triggering.

An adjusted analysis was not pre-specified in the study protocol. We conducted sensitivity analyses adjusting for potential residual imbalances in factors such as baseline diarrhea, the caregiver's education, household income level, the household head's religion, the caregiver's age, the child's age and sex, and the type of water source for drinking. For the adjusted analysis, we referred to a previous study modeling risk categories to predict child diarrhea.[33] We did not include handwashing practices, latrine utilization, and the like because we think that these variables are mediators between the variables we already included in the adjusted analysis and diarrhea.

We estimated the risk difference (RD) of secondary or intermediary outcomes (the proportion of households with an improved latrine and presence of human feces inside or outside of a household compound) using ordinary least squares linear regression with robust standard errors, taking into account correlated outcomes within villages. As an additional analysis, we also ran a GEE analysis to find RRs for the secondary outcomes. In addition, as a supplementary analysis, we calculated the rate ratio of fly counts, using negative binominal regression analysis by aggregation of fly counts around the pit-hole at the village level, and with use of the number of households with any type of latrine in a village as exposure. We used multilevel mixed effect linear regression to calculate the mean difference in diarrhea duration. All standard errors were adjusted for clustering.

Results

There were a total of 1737 households (1301 under-5 children) in the intervention villages and 1795 households (1339 under-5 children) in the control villages at baseline.

At first recruitment, the study population included 1070 children younger than 5 years (539 in the intervention and 530 in the control group). At the second visit for cross-checking the adequacy of the registration, 84 and 80 registered children were excluded because they were found to be living in other villages, were unidentified, or double-entered (i.e., living in the same households); thus, 906 households (mean 25 [SD 14] children per village) remained registered (455 households from the intervention group and 451 households from the control group). We were able to follow 409 (90%) and 433 children (96%) for the incidence and longitudinal prevalence of diarrhea in the intervention and control groups, respectively, for the full 140 days (Figure 1a). Follow-up data were collected from June 9, 2016 through January 23, 2017. For period prevalence, four rounds of follow-up surveys were carried out at 3, 5, 9, and 10 months after the CLTS triggering between February 11 and March 18, 2016. In total, 439 (96%) and 426 (94%) households were followed-up at 10 months after the triggering in the intervention and control groups, respectively (Figure 1b). We found no significant differences in socioeconomic and demographic characteristics between the caregivers and children who were retained in the trial and those who were lost to follow-up (Supplementary material, Table S1).

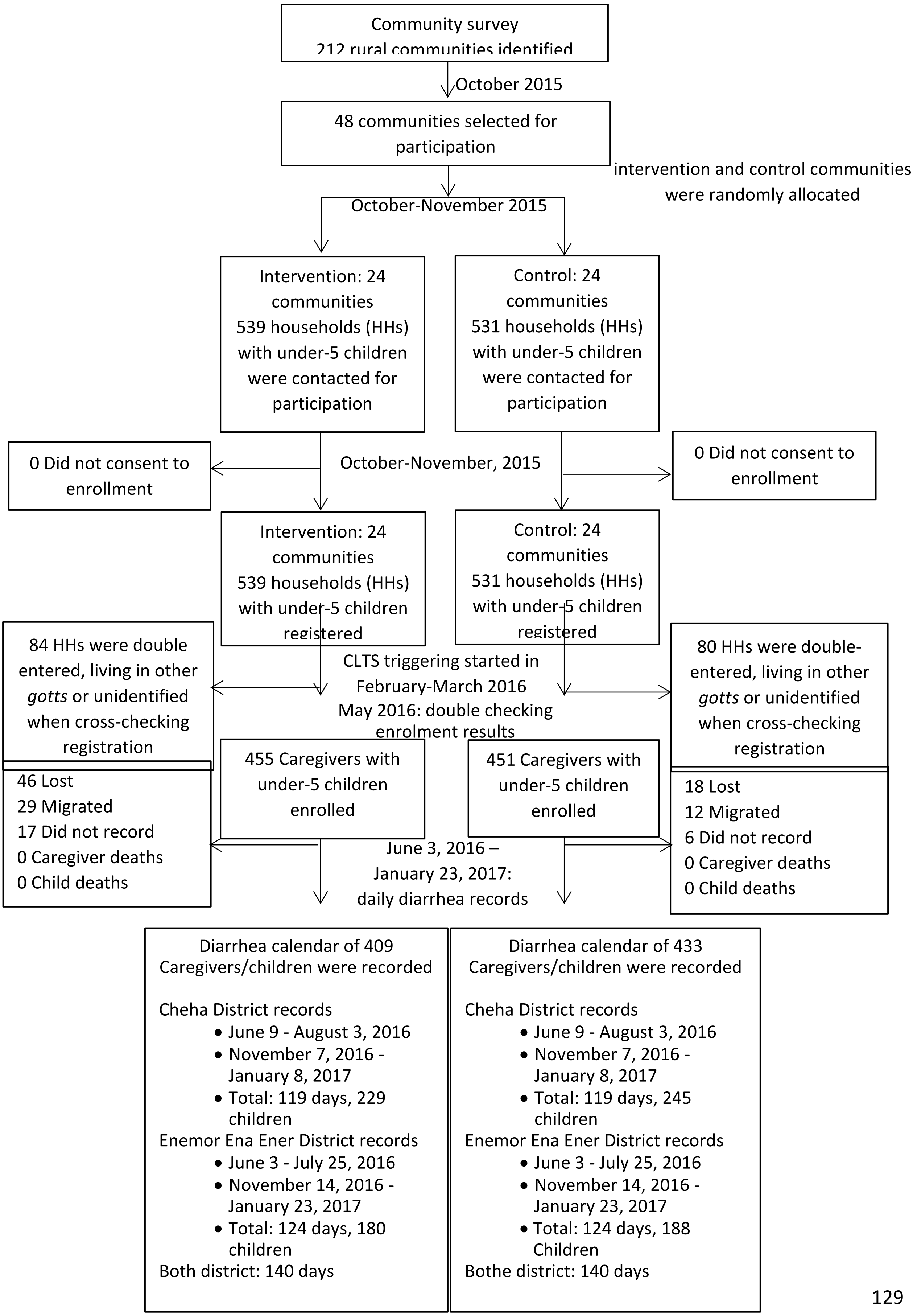

Figure 1a. Flow diagram for the longitudinal prevalence of child diarrhea

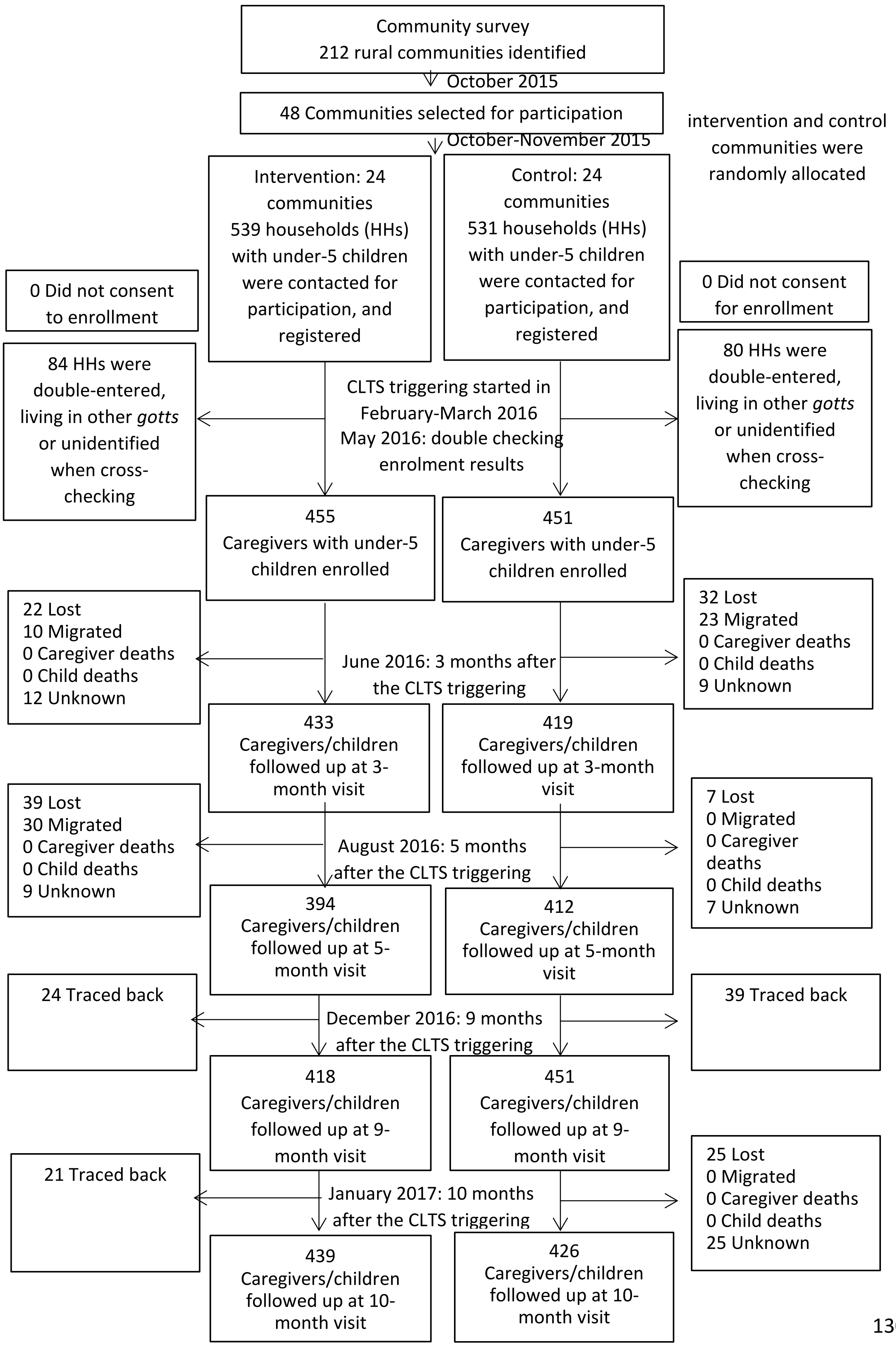
Community survey
212 rural communities identified
October 2015
48 Communities selected for participation
October-November 2015
intervention and control communities were randomly allocated
Intervention: 24 communities 539 households (HHs) with under-5 children were contacted for participation, and registered
Control: 24 communities 531 households (HHs) with under-5 children were contacted for participation, and registered
0 Did not consent to enrollment
0 Did not consent for enrollment
84 HHs were double-entered, living in other *gotts* or unidentified when cross-checking
CLTS triggering started in February-March 2016
May 2016: double checking enrolment results
80 HHs were double-entered, living in other *gotts* or unidentified when cross-checking
455 Caregivers with under-5 children enrolled
451 Caregivers with under-5 children enrolled
22 Lost
10 Migrated
0 Caregiver deaths
0 Child deaths
12 Unknown
June 2016: 3 months after the CLTS triggering
32 Lost
23 Migrated
0 Caregiver deaths
0 Child deaths
9 Unknown
433 Caregivers/children followed up at 3-month visit
419 Caregivers/children followed up at 3-month visit
39 Lost
30 Migrated
0 Caregiver deaths
0 Child deaths
9 Unknown
August 2016: 5 months after the CLTS triggering
7 Lost
0 Migrated
0 Caregiver deaths
0 Child deaths
7 Unknown
394 Caregivers/children followed up at 5-month visit
412 Caregivers/children followed up at 5-month visit
24 Traced back
December 2016: 9 months after the CLTS triggering
39 Traced back
418 Caregivers/children followed up at 9-month visit
451 Caregivers/children followed up at 9-month visit
21 Traced back
January 2017: 10 months after the CLTS triggering
25 Lost
0 Migrated
0 Caregiver deaths
0 Child deaths
25 Unknown
439 Caregivers/children followed up at 10-month visit
426 Caregivers/children followed up at 10-month visit

Figure 1b. Flow diagram for the period prevalence of child diarrhea

Table 1 presents the baseline characteristics of participants by treatment group. The socioeconomic and demographic characteristics of caregivers and household heads, as well as the handwashing practices of caregivers, were similar across groups. The coverage of improved water and sanitation was lower in the intervention group than in the control group at baseline (p=0.02).

Table 1. Baseline characteristics of the intervention and control groups

	Intervention N=455		Control N=451	
	n or Mean	% or SD	n or Mean	% or SD
Caregiver's gender (female)	446	98.0%	446	98.9%
Caregiver's age	29.9	6	29.6	5.3
Caregiver's education				
None	289	66.4%	289	66.4%
1-4 grades completed	52	12.0%	64	14.7%
Household head's gender (male)	427	93.8%	435	96.5%
Household head's age	37.2	7.9	37.5	7.4
Household head's ethnicity (Gurage)	431	99.1%	433	99.5%
Household head's religion				
Muslim	242	55.6%	286	65.7%
Christian	189	43.4%	149	34.3%
Household head's monthly income (ETB)	829.7	641.5	934.6	739.5
Child's sex (female)	226	49.7%	224	49.7%
Child's age (months)	24.4	16.3	24.1	15.3
Improved water for drinking	319	72.7%	347	76.9%
Reported hand-washing practices				
Before eating	411	90.3%	388	86.0%
After defecating	295	64.8%	286	63.4%
Before food preparation	378	83.1%	356	78.9%
After cleaning child's buttocks	118	25.9%	140	31.0%
Before feeding a child	164	36.0%	169	37.5%
Child diarrhea (7-day period prevalence)	101	22.2%	77	17.1%
Having household latrine (self-reports)	341	74.9%	364	80.7%
Latrine structure (direct observation)				
Pit	320	70.3%	342	75.8%
Slab	313	68.8%	336	74.5%
Hole cover	57	12.5%	54	12.0%
Wall	178	39.1%	184	40.8%
Roof	143	31.4%	140	31.0%
Door	35	7.7%	42	9.3%
Handwashing facility with soap	39	8.6%	36	8.0%
Pit depth (meters)	1.64	0.870	1.79	0.740
improved latrine[a]	0	0.0%	3	0.7%
partially improved latrine or better[b]	55	12.1%	50	11.1%
Latrine utilization				
Direct observation (Composite[c])	100	25.2%	109	24.7%
Cleanliness				
Presence of flies				
Presence of feces around pit hole	76	16.7%	102	22.6%
Open defecation				
Feces inside household compound	73	16.0%	63	14.0%
Feces outside household compound	83	18.2%	68	15.1%
Child feces disposal				
Into latrine	322	70.8%	340	75.4%

	Intervention N=455		Control N=451	
	n or Mean	% or SD	n or Mean	% or SD
Open field	76	16.7%	55	12.2%

[a] An improved latrine was defined as having a pit deeper than 2 meters, a pit-hole cover, slab, wall, door, roof, and a handwashing facility with soap; [b]A partially improved latrine was defined as having a pit, a pit-hole cover, and slab; [c] Composite: presence of wet feces, foot print and odor, and absence of spider web

Table 2 shows the effects of the intervention on the incidence and longitudinal prevalence of child diarrhea based on calendar records. There were 202 cases (481 days of diarrhea) in the intervention group and 298 cases (773 days of diarrhea) in the control group during the 140 days of follow-up (Table 2 and Figure 2). The corresponding incidence ratio and the longitudinal prevalence ratio were 0.66 (95% confidence interval [CI]: 0.45-0.97, p=0.03) and 0.70 (95% CI: 0.52-0.95, p=0.02), respectively, after adjusting for clustering and stratification. The effects of the intervention on the duration of child diarrhea is shown in Table 3. The results of the CLTS intervention on diarrhea duration are deemed compatible with there being no effect (95% CI: -0.8 to 0.4 days, p=0.48).

Table 2. Effects of the CLTS intervention on the incidence and longitudinal prevalence of diarrhea (based on calendar records)

	Intervention	Control	95% CI	p-value
Total days of diarrhea	481(334[a]/147[b])	773(551[a]/222[b])		
Total episodes	202(138[a]/64[b])	298(220[a]/78[b])		
Total children	409	433		
Person-days	49571	52467		
Incidence (*100 days)	0.4	0.5		
Incidence ratio[c]	0.66		0.45-0.97	0.03
Incidence ratio[d]	0.66		0.45-0.97	0.04
Longitudinal prevalence (*100 days)	1.0	1.5		
Longitudinal prevalence ratio[c]	0.70		0.52-0.95	0.02
Longitudinal prevalence ratio[d]	0.70		0.51-0.95	0.02

[a]The results for the first 62 days of the entire 140 days (The CLTS triggering was carried out in February and March 2016. Starting in June 3, 2016 child diarrhea presence was recorded for 140 days until January 23, 2017. There was a 3-month interval in the diary records to avoid caregiver fatigue.)
[b]The results for the next 78 days of the entire 140 days
[c]Adjusted for clustering effect and stratification (*kebele*).
[d]Adjusted for clustering effect and stratification (*kebele*), household head's religion, income, caregiver's age and education level, child's age and sex, and type of water source
The separated incidence and longitudinal prevalence by period are presented in Supplementary material Table S2. An additional analysis adjusting for more variables is described in Supplementary material Table S3.

Table 3. Effects of the CLTS intervention on diarrhea duration (based on calendars)

	Diarrhea episodes with an interval of 2 or more days ‡	
	Intervention	Control
Total episodes	202	298
Total children	409	433
Duration of diarrhea		
1 day	90 (45%)	124 (41%)
2 days	56 (28%)	91 (31%)
3 days	32 (16%)	36 (12%)
4 days	13 (6%)	18 (6%)
More than 4 days	11 (5%)	29 (10%)
Mean duration (days)	2.4	2.6
Mean difference (days)[a]	-0.2	
95% CI	-0.8, 0.4	
p-value	0.48	
Mean difference (days)[b]	-0.2	
95% CI	-0.8, 0.4	
p-value	0.58	

[a]Adjusted for clustering effect and stratification (*kebele*)

[b]Adjusted for clustering effect and stratification, household head's religion, income, caregiver's age and education level, child's age and sex, and type of water source

An additional analysis adjusting for more variables is described in Supplementary material, Table S4.

Table 4 shows that the 7-day period prevalence of child diarrhea based on caregiver's recall decreased from 22.2% at baseline to 11.8% at the 3-month follow-up and 7.7% at the 10-month follow-up in the intervention group. The prevalence rose from 17.1% at baseline to 17.2%, and declined to 9.9% at the same time points in the control group. The relative risk of period prevalence adjusted for clustering effects and stratification was 0.66 (95% CI: 0.45-0.98, p=0.04) at 3 months and 0.75 (95% CI: 0.35-1.60, p=0.45) at 10 months after the triggering. Pooling the four rounds of follow-up surveys, the overall relative risk of period prevalence was 0.83 (95% CI: 0.60-1.13, p=0.23). Except for the first 3 months, there was no significant impact on child diarrhea prevalence. All the effects on longitudinal prevalence, incidence (Supplementary material, Table S2), and period prevalence appeared to wane over time.

Table 4. Effects of the CLTS intervention on the 7-day period prevalence

	Period prevalence							
	CLTS (455)[a]	Control (451)[a]	Relative Risk[b]	95% CI	p	Relative Risk[c]	95% CI	p
Overall			0.83	0.60-1.13	0.23	0.78	0.56-1.10	0.16
3 months (June 2016)	11.8% (51/433)	17.2% (72/419)	0.66	0.45-0.98	0.04	0.60	0.39-0.93	0.02
5 months (August 2016)	17.3% (68/394)	17.5% (72/412)	0.98	0.68-1.39	0.89	0.89	0.61-1.29	0.54
9 months (December 2016)	10.5% (44/418)	11.8% (53/451)	0.87	0.52-1.48	0.62	0.87	0.50-1.49	0.61
10 months (January 2017)	7.7% (34/439)	9.9% (42/426)	0.75	0.35-1.60	0.45	0.63	0.28-1.43	0.27

[a]Sample sizes at baseline
[b]Adjusted for clustering effect, stratification (*kebele*).
[c]Adjusted for clustering effect, stratification (*kebele*), baseline prevalence of diarrhea, household head's religion, income, caregiver's age and education level, child's age and sex, and type of water source.
An additional analysis adjusting for more variables is described in Supplementary material, Table S5.

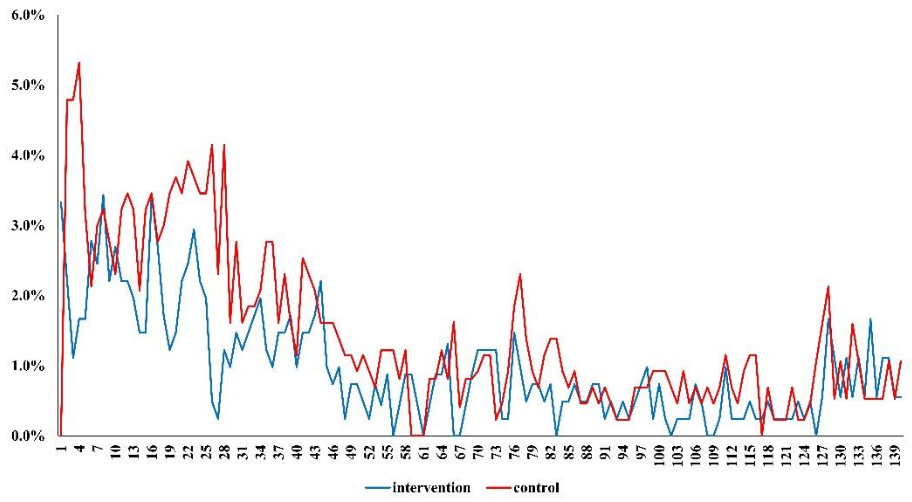

Figure 2. Daily prevalence of diarrhea based on calendar records (one unit of x-axis 51day; the first day on the x-axis is at 3 months after the CLTS initiation).

Table 5 shows that the mean proportion of households with an improved latrine increased from 0.0% at baseline to 35.0% at 10 months after the CLTS triggering in the intervention villages, while it increased from 0.5% to 2.8% in the control villages (risk difference: 32.3%, 95% CI: 19.1%-45.4%, p<0.001; see Supplementary materials, Table S6 and S7 for the results at 3, 5, 9, and 10 months).

At the 10-month follow-up, four of the 24 intervention villages had improved latrine coverage of 70% or greater. Meanwhile, in the control villages, no community had a coverage of 30% or greater. Ownership of a partially improved household latrine (defined as having a pit, pit-hole cover, and slab) in this study rose from 11.9% at baseline to 69.0% at 10 months after the CLTS triggering in the intervention group, compared with the corresponding rates of 11.6% at baseline and 15.0% at follow-up in the control group (risk difference: 53.8%, 95% CI: 43.2%-64.3%, p<0.001). The coverage of any type of latrine was already high at baseline and continued to increase in both arms. Based on the results of direct observations, the coverage of any type of latrine at baseline in the intervention villages was 70.3% and increased to 99.5% 10 months after the CLTS triggering, and the corresponding values in the control group were 75.8% at baseline and 90.8% at 10 months of follow-up.

All caregivers who had any type of latrine in both the intervention and control groups reported that they were using the latrine at the 10-month follow-up (99.5% vs 90.8% in the intervention and control group, respectively; risk difference: 8.7%, 95% CI: 3.8%-13.6%, p<0.001). The latrine utilization rate based on direct observation, however, was far below that of the self-reports. We found no consistent pattern of the effect of the intervention on latrine utilization (Supplementary Table S6). Latrine utilization was not significantly different at 10 months after the CLTS triggering (January, 2017) between the two groups on the basis of the composite indicator comprising the presence of wet feces, foot print and odor, and absence of spider webs. The intervention had an effect on contamination pathways, as shown by some indicators. We recorded a declining trend in the presence of feces inside and in the immediate surroundings of the household compound (within 10 feet) in the intervention group compared with the control group. Fly count also decreased in the intervention group compared to the control villages. The proportion of households with human feces inside the household compound decreased from 16% at baseline to 1.6% in the intervention group, while it declined from 14% to 7.4% in the control group (risk difference: -6.1%, 95% CI -11.4% to -0.8%, p=0.03) at the 9-month follow-up (Supplementary Table S6). The number of flies around the pit hole of a latrine was smaller in the intervention group than in the control group (rate ratio [RR] 0.60, 95% CI: 0.45-0.78, p<0.001; RR 0.39, 95% CI: 0.31-0.49, p<0.001, at 9 and 10 months, respectively).

Table 5. Effects of the CLTS intervention on secondary and intermediate outcomes

Survey period	10 months after the CLTS triggering (January, 2017)				
	Intervention	Control	RD/ RR[d]	95% CI	p
Outcomes	(N=439)	(N=426)			
Having a household latrine					
All types of latrine	437 (99.5%)	387 (90.8%)	8.7%	3.8%, 13.6%	<0.001
Improved latrine[a]	154 (35.0%)	12 (2.8%)	32.3%	19.1%,45.4%	<0.001
Partially improved latrine or better[b]	302 (69.0%)	64 (15.0%)	53.8%	43.2%,64.3%	<0.001
Hand washing facility	207 (47.2%)	49 (11.5%)	35.6%	19.5%, 51.7%	<0.001
Latrine Utilization/Self-report	437 (99.5%)	387 (90.8%)	8.7%	3.8%, 13.6%	<0.001
Latrine Utilization/Use					
Direct observations (Composite)[c]	162 (36.9%)	191 (44.8%)	-8.6%	-32.8%, 15.6%	0.47
Feces around pit hole	63 (14.4%)	100 (25.8%)	-11.4%	-28.8%,-5.9%	0.02
Feces in the compound	7 (1.6%)	30 (7.4%)	-5.4%	-11.8%,0.9%	0.09
Feces outside compound	5 (1.1%)	24 (5.6%)	-4.5%	-9.4%,0.4%	0.07
Fly number	3.9 (6.9)	7.6 (7.9)	0.39	0.31, 0.49	<0.001
Child feces disposal	436 (99.3%)	384 (90.10%)	2.6%	-0.9%,6.1%	0.14
Reported Hand washing at five critical times	194 (44.2%)	143 (33.6%)	10.6%	-12.6%,33.8%	0.37

[a] An improved latrine was defined as having a pit deeper than 2 meters, a pit-hole cover, slab, wall, door, roof, and a handwashing facility with soap; latrine depth was not measured at the 5-month follow-up, and thus the proportion of improved latrines was not assessed

[b] A partially improved latrine was defined as having a pit, a pit-hole cover, and slab: this row includes both improved and partially improved latrines.

[c] Composite: presence of wet feces, foot print and odor, and absence of spider web

[d] RD: Risk Difference, RR: Rate Ratio for fly counts (aggregated at village level).

See Supplementary Table S6 for the results at 3, 5 and 9 months; Supplementary Table S7 for the results in Relative Risk at 3, 5, 9 and 10 months

Discussion

Our findings provide evidence that the CLTS intervention in rural areas of Ethiopia reduced the incidence and the longitudinal prevalence of child diarrhea and increased the coverage of an improved household latrine from 3 to 10 months after CLTS triggering. This study also found that the sanitation intervention reduced exposure to transmission pathways of fecal-oral contamination in terms of fly count. However, there was no clear evidence of effect on 7-day period prevalence over longer follow-up duration beyond three months and duration of diarrhea. Also, we detected no effect on the use of household latrines.

The effect size of the CLTS interventions in this study was consistent with recent systematic reviews on the effect of sanitation improvements on child diarrhea (e.g., relative risk: 0.75, 95% CI: 0.63-0.88, $p<0.001$ in the latest study).[7,8]

Our results build on previous trials and explain lack of impacts in previous trials of sanitation interventions.[9-13] The majority of previous trials reporting no effects of sanitation improvements suggested that the absence of an effect might have been caused by insufficient coverage and use of latrines.[9-13] Previous studies suggested that the absence of an effect of a sanitation intervention could be explained by the possibility that household sanitation improvements alone were insufficient to mitigate transmission of fecal pathogens, or that the latrines themselves were ineffective at containing excreta.[9,11] In particular, previous researchers expressed concerns that handwashing practices, food hygiene, and protection against contamination of animal feces could not be handled solely by improving household sanitation. The importance of these components cannot be overstated; however, this study suggests that improvement in household sanitation alone could have protective benefits against child diarrhea. Interestingly, a profound effect of a sanitation intervention was reported in this study even though the proportion of latrine use was not different between the treatment arms.

However, the absence of a difference in the use of any type of latrine between the groups means that the use of an improved or a partially improved latrine was higher in the intervention arm than in the control arm. The fact that there was near-universal coverage of any type of latrine, and a sizeable proportion of quality latrines, at least partially improved latrines, and more widespread use of improved latrines might have contributed to reducing diarrhea. We believe that improved latrine status was one of the most plausible factors contributing to diarrhea reduction. A clear piece of evidence in this regard is the significant reduction in the fly count around pit-holes in the intervention group compared with the control group. This finding is consistent with the result of a previous study by Chavasse and colleagues, in which the incidence ratio of diarrhea was 0.77 (95% CI, 0.67-0.89, p=0.007) in the fly seasons after controlling flies compared with the control group.[34]

In addition, the increase in the proportions of household latrines with slab or handwashing facilities in the intervention group might also have reduced the possibility of contact with feces via hands or feet, although these were not measured. The handwashing practices of caregivers after defecating were somewhat better in the intervention group at 3 months after the CLTS triggering (Supplementary Table S8). Furthermore, the handwashing practices of caregivers at five critical times (before eating, after defecating, before food preparation, after cleaning a child's buttocks, and before feeding a child) tended to be slightly higher compared with those in the control group. However, the difference was minimal. The decrease in the presence of human feces inside or outside of the household compound could also be another reason for diarrhea reduction in the intervention group. Similarly, animals might have been less likely to transmit pathogens of human feces in the intervention group because of the increase in the coverage of latrines with a wall.[35-37] Another reason for the absence of an effect in other trials may lie in the frequency of measurements.[32] In previous trials, diarrhea measurements were done only once or at a few time points.[9-11,13] A typical measurement point in previous trials was

12 months after the intervention. We assessed diarrhea cases throughout the rainy (June-August) and dry seasons. Diarrheal illness was measured at 140 time points from 3 months to 10 months after the CLTS triggering. If we had assessed diarrhea prevalence only at 10 months after the triggering, we would not have been able to detect the effects of the CLTS intervention in this study.

Trials in Kenya and Zimbabwe encouraged households to shift from unimproved to improved sanitation.[9,13] However, in those studies, the investigators applied a compound-based approach rather than a community-based intervention, and the community-wide coverage of improved latrines remained low at follow-up, even though the rate was very high among the households that received the intervention. Although Ngure et al. argued that children under 2 years are mostly exposed to fecal contamination within household compounds, this tendency might be highly context-dependent, and thus a compound-level sanitation intervention might not be sufficient to protect children from exposure to fecal contamination, particularly when only a small proportion of households in a community receive a sanitation intervention, as in the trials in Kenya and Zimbabwe.[9,13,38] Herd protection from sanitation interventions or external effect of community-wide sanitation coverage was suggested in previous studies.[39,40]

In the first CLTS trial to assess an effect on child diarrhea, the proportion of households with a household latrine was 65% in the intervention group, but most of the latrines were unimproved.[11] In our study, the proportion of household latrines with a slab reached 99% at 10 months after the triggering (Supplementary Table S6). We found a consistent pattern of a smaller number of feces around-holes and lower fly counts in improved latrines compared with unimproved latrines within the villages that received the intervention (Supplementary Table S9). It is worth noting that even the partially improved latrines in this study fell into the category of an improved latrine according to the WHO/UNICEF Joint Monitoring Program.[5]

It has been hypothesized that sanitation coverage must be greater than a certain threshold for adequate prevention of transmission of diarrheal pathogens. We think that the effect of the CLTS intervention on child diarrhea reduction in this study might have been caused by near universal coverage of improved latrines based on the WHO/UNICEF definition.[5]

A substantial reduction in child diarrhea cases was observed over time in the control group. A possible explanation was contamination of the intervention, in that improvements in sanitation coverage and transmission pathways were observed in the control group (e.g., the presence of feces inside or outside a household compound, ownership of an improved or partially improved latrine, safe disposal of children's feces). Another explanation for the diarrhea reduction in the control villages is the reduced risk of diarrheal illness during the dry season (September-May), although opposing findings have sometimes been reported.[41,42]

Daily diarrhea episodes decreased over time both in the intervention and the control villages. We infer that seasonal variation and the increased coverage of partially improved latrines even in the control group could have contributed to this change. We noticed that the reduction in diarrhea in the intervention group was more substantial during the earlier period of the CLTS intervention in terms of longitudinal prevalence and incidence (Supplementary Table S2). This is consistent with the fact that the coverage of improved and partially improved latrines increased more substantially in the early period of the intervention, as shown by 26.6% and 42.4% increases in improved and at least partially improved latrine coverage for the first 3 months, in comparison to 8.4% and 14.5% increases during the next 7-month period (Supplementary Table S6).

This study has several limitations. First, we relied on caregivers' reports or records of child diarrhea, and did not conduct molecular measurements of infection; thus, we cannot rule out the possibility of bias. The inability to mask the CLTS intervention is another limitation.

Adequate disposal of child feces or handwashing behavior might have been overstated, similarly to how the self-reported use of a household latrine was higher than the results of direct observations. To overcome the social desirability bias, we relied on the results of direct observations for latrine construction and utilization. CLTS promoters in the intervention arm might have been a potential contamination channel in the control group through their monthly checks and follow-up on diarrhea diaries. The increases in partially improved latrines and hand-washing facilities in the control villages could be partially explained by this factor.

This study reported that a number of indicators had improved more at the 10-month follow-up than at earlier times after the triggering, and it may be possible that the effect on the incidence and the longitudinal prevalence of child diarrhea could have been more pronounced with a longer follow-up period if post-triggering activities had continued. This possibility is especially compelling since the households with partially improved latrines were in the process of constructing improved household latrines.[43,44] However, this does not guarantee that the outcomes can be sustained after post-triggering or post-ODF activities stop. Previous studies suggested that the effects of an intervention may wane over time, particularly beyond 1 year after an intervention.[9] We suggest institutionalizing a system for sanitation improvement so that post-triggering or post-ODF activities can be routinely carried out by government officials, community health workers, and the like.[44]

Adherence to the intervention in terms of ownership of an improved or partially improved latrine was comparable to the majority of previous studies. However, caution is needed when interpreting the generalizability of this study. This trial was done in rural areas with high coverage of simple pit latrines and a low proportion of open defecation practices even before the CLTS intervention. Highlighting improved latrines from the onset of CLTS interventions might be difficult in other contexts, particularly where open defecation practices are rampant and latrine coverage is low. The relatively small number of clusters in this study compared with other previous trials might have helped in the implementation of an intensive intervention, particularly during the post-triggering period. In this regard, it remains unanswered whether the findings of this study are replicable and relevant for large-scale interventions, and whether similar improvements and effects can be achieved at scale. Still, this trial provides evidence that CLTS interventions with an emphasis on improved household latrines are likely to reduce child diarrhea. Importantly, while reducing barriers against latrine construction by encouraging community members to use locally available and affordable materials, we did not compromise the improved status of latrines nor neglect the principle of no financial or material subsidy.

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Chapter 5. Performance of pit latrines

The following research paper addresses research objective 2): analyse the performance of pit latrines by type and explore the presence of sanitation externalities.

This chapter provides an overview of the performance of various types of pit latrines, as well as the results of an analysis of the herd protective effects of these latrines. This study examined whether the risk of diarrhea in children under-five differs between those residing in households with unimproved latrines and those with JMP-improved latrines, as defined by the Joint Monitoring Programme (JMP). It also compared the odds between those living with a JMP-improved latrine and those with a study-improved latrine as operationally defined by this study. Furthermore, it investigated the presence of sanitation externality.

RESEARCH PAPER COVER SHEET

Please note that a cover sheet must be completed for each research paper included within a thesis.

SECTION A-Student Details

Student ID Number	Lsh157351	**Title**	Dr.
First Name(s)	Seungman		
Surname/Family Name	Cha		
Thesis Title	Evaluation of a community-led total sanitation intervention in a rural area of the Southern Nations, Nationalities, and Peoples' Region, Ethiopia		
Primary Supervisor	Wolf Schmidt		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

SECTION B-Paper already published

Where was the work published?	Global Health: Science and Practice		
When was the work published?	27 June 2024		
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SECTION C-Prepared for publication, but not yet published

Where is the work intended to be published?	Global Health: Science and Practice
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For multi-authored work, give details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	**SC** and SJ conceived and designed the study; SJ, TA and DBB coordinated the data collection; **SC** developed the data analysis plan; SJ, TA and DBB contributed to project administration; **SC** and YJ analyzed the data and interpreted the results; TA and ET contributed to data curation; **SC** wrote the first draft; W-PS and IR contributed importantly to the theoretical and practical considerations of the analysis and interpretation.

SECTION E

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Performance of pit latrines and their herd protection against diarrhea: a longitudinal cohort study in rural Ethiopia

Short titles: Performance of pit latrines and their herd protection against diarrhea

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Teaser Key Messages

① Policymakers should advocate for universal health coverage of water, sanitation, and hygiene interventions to confer herd protection against disease transmission.

② Future research should investigate the relationship between latrine design and health outcomes.

Key Messages

① We compared the performance of a well-constructed latrine with a pit of 2 m or more depth, slab of any material, drop-hole cover, wall, roof, door, and handwashing facilities (water and soap observed) with a poorly constructed one, missing 1 or more of these features or having only a pit latrine with a slab, on interrupting the fecal-oral transmission pathway and reducing child diarrhea.

② Children living in households with a well-constructed latrine were less likely to have diarrhea than those living in households with a poorly constructed one.

③ In villages with 50% or more of households having well-constructed latrines and 70% or more of households having a pit latrine with a slab (high coverage), children living in a household with no latrine or a poorly constructed one were less likely to contract diarrhea than those with no latrine or a poorly constructed one in a village with low coverage.

Author contributions: SC and SJ conceived and designed the study; SJ, TA and DBB coordinated the data collection; SC developed the data analysis plan; SJ, TA and DBB contributed to project administration; SC and YJ analyzed the data and interpreted the results; TA and ET contributed to data curation; SC wrote the first draft; W-PS and IR contributed importantly to the theoretical and practical considerations of the analysis and interpretation; All authors reviewed, critically revised, and approved the final version of this manuscript before submission.

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Abstract

In sanitation policies, “improved sanitation” is often broadly described as a goal with little rationale for the minimum standard required. We conducted a secondary analysis of data collected as part of a cluster randomized controlled trial in rural Ethiopia. We compared the performance of well-constructed and poorly constructed pit latrines in reducing child diarrhea. In addition, we explored whether having a well-constructed household latrine provides indirect protection to neighbors if cluster-level coverage reaches a certain threshold. We followed up under-five children of 906 households in rural areas of the Gurage zone, Ethiopia for 10 months after CLTS interventions. A study-improved latrine was defined as having all of the following: pit of ≥2m depth, slab of any material, drop-hole cover, wall, roof, door, and handwashing facilities (water and soap observed). Children under 5 years in households with a study-improved latrine had 54% lower odds of contracting diarrhea than those living in households with a study-unimproved latrine missing one or more of the above characteristics (adjusted odds ratio [aOR]=0.46, 95% confidence interval [CI]=0.27-0.81, p=0.006). Analyses were adjusted for child age and sex, the presence of improved water for drinking, and self-reported handwashing at four critical times. The odds of having diarrhea among those with an improved latrine based on the WHO/UNICEF Joint Monitoring Program (JMP) definition (i.e., pit latrines with slabs) were not substantially different from those classified as unimproved by the JMP definition (aOR=0.99, 95% CI=0.56-1.79, p=0.99). Of the children living in households without a latrine or with a study-unimproved latrine, those in the high-coverage villages were less likely to contract diarrhea than those in low-coverage villages (aOR=0.55; 95% CI=0.35-0.86, p=0.008). We recommend that academic studies and routine programme monitoring and evaluation should measure more latrine characteristics and evaluate multiple latrine categories instead of making binary comparisons only.

Introduction

Disposing human excreta into the ground has been practiced for thousands of years.[1] Proper disposal of excreta improves human health and quality of life, contributing to socioeconomic development.[2-5] Pit latrines are the most common form of sanitation in many countries.[6] In 2017, 3.1 billion people were reported to use improved on-site sanitation facilities, and an estimated 701 million people used unimproved on-site sanitation facilities including pit latrines without a slab or platform for their excreta disposal.[6] Pit latrines are a commonly recommended sanitation system for populations likely to be constructing household latrines using locally available and affordable materials.[7] This is particularly the case in remote rural areas, where community-led total sanitation (CLTS) interventions are being carried out without any material or financial subsidies.[7]

Pit latrines are considered to be the first rung of the sanitation ladder above open defecation, from which people can continue climbing to higher levels of service.[7] The key reasons for uptake of pit latrines in many low income countries lie in the following features: pit latrines are simple to construct, easy to operate and maintain, and easy to use for the disposal of various bulky anal cleansing materials.[1] To dispose of human excreta safely, the pit content should not come into direct contact with humans, insects, or animals.[8,9]

In accordance with these trends, many sub-Saharan African countries adopted and promoted pit latrines.[10,11] A pit latrine with a slab has been considered an improved latrine by UNICEF since 2008. However, some have highlighted the importance of hygienic latrines beyond the "improved sanitation" defined by the Millennium Development Goals.[12-14] Against this backdrop, a number of countries in sub-Saharan Africa have adopted policies for sanitation improvements, but there was little emphasis on the minimum standard of pit latrines required for disrupting transmission of fecal-oral pathogens, with the exception of a few countries.[1,15,16]

For instance, Kenya government released a sanitation policy highlighting the importance of accessibility to the safe sanitation facilities, which provided a range of sanitation technology options. According to this policy, "at least an upgraded pit latrine" is the minimum requirement, "provision of super structures, covering of the pit opening/squat hole with a suitable cover, plastering of the latrine floor with cement and introduction of a vent pipe to improve the hygiene conditions of the latrine" was taken as an example for "at least an upgraded pit latrine".[17] In Sudan's sanitation policy, by contrast, latrine design was not highlighted within specific strategies, although it did outline the sanitation ladder including improved facilities.[18]

Despite the prevailing view of latrine improvement as an intervention that promotes health, it should be kept in mind that latrines could, in fact, play a role in transmitting disease if they are badly constructed.[19] For instance, some low-quality latrines taken up after CLTS interventions have sometimes been criticized as involving "fixed point open defecation", by collecting excreta in one place nearer the household but still accessible to animals/flies.[20] In this regard, achieving the open defecation-free status, as it is generally defined, might end up disseminating "fixed point open defecation" practices if CLTS implementers are not cautious about latrine design. Thus, we need to understand the minimum standard of pit latrine design for sanitation interventions to help interrupt the transmission. Although there are different types of pit latrines, it is currently unclear which latrine characteristics help disrupt fecal-oral transmission.[1,21,22] According to a review of the performance of pit latrines, despite their widespread application and use across the globe, the relationship between latrine type or design and performance on health outcomes has not been thoroughly assessed.[1] Previous studies have mainly focused on latrine coverage, not categorizing latrines by type or design.

Herd protection refers to the phenomenon where an intervention against an infectious disease offers indirect protection to individuals who have not received the intervention. When there is a herd protective effect from an intervention targeting infectious diseases that are transmitted from person-to-person or when humans are important reservoirs of the pathogen, the intervention can reduce the risk of infection among those who have not received it. Sanitation interventions have been thought to provide herd-protective effects.[23] If a herd protection effect exists, children living in a household without a latrine in a village with high latrine coverage may be less likely to have diarrhea than those without a latrine in a village with low coverage. In other words, having a household latrine provides indirect protection to those who do not have a household latrine in a village with high latrine coverage. However, this concept has not been thoroughly investigated in the field of sanitation, and empirical studies exploring the herd protection offered by sanitation interventions are scarce.[24-27] Some studies have attempted to investigate herd protection against infectious diseases, childhood nutrition, or mortality from drinking water, sanitation, and/or hygiene interventions.[28-37] Some studies suggested that sanitation coverage provides indirect effect against some diseases such as trachoma and malaria, and on nutritional outcomes. Studies investigating herd protective effects of water and sanitation on child diarrhea are scarce and few studies examined externalities of sanitation coverage by latrine type.[28-30,38-43]

Fuller and colleagues estimated the herd protection effect of sanitation improvements using hypothetical mathematical modeling.[23] They highlighted the knowledge gap in empirical research assessing the herd protective effects of sanitation interventions. A recent study on the spill-over effects of sanitation also has pointed out the knowledge gap on the herd protective effects of water and sanitation interventions.[44] In another recent study[45], it was found that higher community sanitation coverage was linked to improved child health, including a reduction in diarrhea. However, coverage with exclusively hygienic latrines did not show a significant association with outcomes, indicating a need for further research.[45]"

We aimed to investigate whether relatively well-designed pit latrines conferred greater health benefits than poorly constructed ones. We compared the performance of well-constructed and poorly constructed pit latrines on reducing child diarrhea. We also explored to what extent indicators of fecal-oral transmission pathways, such as the presence of feces or flies around the pit hole, are associated with latrine design or structure. In addition, we explored whether children living in a household without a latrine or with a poorly structured latrine in a village with high coverage are less likely to have diarrhea than those living in a household without a latrine or with a poorly structured latrine in a village with low coverage.

Methods

Study design and data collection

This is a secondary analysis of data collected alongside a cluster randomized controlled trial (cRCT) that was conducted in two districts in Ethiopia to investigate the effect of CLTS on child diarrhea. The study protocol of the cRCT was published previously[46] as were studies on the health and economic effects of the CLTS intervention.[47.48] The trial was conducted from January 2016 to January 2017. The 7-day period prevalence of child diarrhea based on parental reports was assessed 3 months before and 3, 5, 9, and 10 months after the CLTS triggering. The same dataset for evaluating the health and economic effects of the CLTS intervention was used for this study. In total, 906 households enrolled in this study in 2015, representing 25.7% of all households and 80.2% of households with at least one under-five child (U5C) in 48 villages. Of those enrolled, 865 (95.5%) were followed up at 12-13 months after enrollment.

Study area

The study areas were the *Cheha* and *Enemore Ena Ener* Districts, which are located 185 km to the southwest of *Addis Ababa*, the capital city of Ethiopia. The population of each district was 133,233 and 204,937, respectively, in 2014. Crop production, including coffee, *khat*, and oil seeds, is the major income source in these districts. *Guragenya* are the predominant ethnic group, and Muslims and Ethiopian Orthodox Christians comprise 64% and 33% of the population, respectively.

Sampling and sample size

The sample size to design the cRCT was estimated using the formula developed by Hayes and Bennett.[49] The formula produced 48 villages and 1200 households for the trial. Two-stage sampling was employed to select subjects. Forty-eight villages were selected from 212 villages on the basis of having the lowest water and sanitation coverage before the intervention.[46] We then listed all the households with at least one U5C in 48 villages and selected 25 households (an average of 30% of the total eligible) from each village using SPSS version 21 (IBM Corp., Armonk, NY, USA) before the baseline survey. We recruited 1070 households in 48 villages at baseline, which decreased to 906 households before the first round of follow-up because some of the registered children were found to be duplicated or living in the same household.

Intervention

CLTS activities (pre-triggering, triggering, post-triggering, and open defecation-free declaration and verification) were conducted in 24 intervention villages for 10 months in 2016-2017, and details are described in the appendix (Appendix A).[46-47] Pre-triggering and triggering were conducted in February and March 2016, and open defecation-free declaration and verification were carried out in February 2017. Pre-triggering and triggering took one day per village, respectively. Post-triggering activities were done for 10 months after the triggering. CLTS promoters were recruited from every village to mobilize village residents and encourage them to take up household latrines using locally available and affordable materials. No financial or material subsidies were provided to any village residents.

Analysis

We combined the treatment and control groups and re-categorized the households according to the presence and type of a latrine at the household level and coverage per type at the village level regardless of their allocation results in the trial. In this study, a study-improved latrine was defined as having a pit of ≥2m depth, slab of any material, drop-hole cover, wall, roof, door, and handwashing facilities (water and soap observed).[47-48] At the same time, we also analyzed the performance of an improved latrine based on the Joint Monitoring Program (JMP) definition, a pit latrine with a slab, in which case we clearly referred to it as a "JMP-improved latrine.” in this study. We could not carry out some measurements, including pit depth, fly counts, and feces counts due to the heavy floods around the second round of the survey (at 5 months), and therefore were unable to categorize latrines as improved or not. We thus excluded the second round of data. We assessed the demographic and socioeconomic characteristics of caregivers, household heads, and children. Village-wide variables such as the coverage of improved water access, improved latrine, and handwashing at critical times were also estimated. Improved latrine and handwashing practices were measured at every round of the household survey. For improved water, the baseline value was analyzed, assuming that it would remain the same for the 10-month follow-up period since there was no intervention for water source improvement during the CLTS intervention period.

Improved water was defined according to the JMP criteria.[6] For handwashing practices, we defined appropriate handwashing practices as when participants responded, unprompted, that they had washed their hands with soap at all four of the following critical times during the previous day: before preparing food, after defecating, before feeding a child, and after cleaning a child’s anus.

Primary outcomes by latrine type

First, we compared the diarrhea prevalence of children living in households a with study-improved latrine with those in households with a latrine but a study-unimproved one. We also compared the diarrhea prevalence of children living in households with a study-unimproved latrine with those in households without any latrine. We focused on investigating whether diarrhea prevalence was different between children according to the presence of a study-improved or study-unimproved latrine in their household. Second, we compared the presence of feces and flies around the pit-hole between study-improved and study-unimproved latrines. Feces were counted on the spot by enumerators. Flies were caught by a glue trap of the same length put around a pit-hole for 30 minutes. Similarly, we assessed latrine utilization using four different proxy indicators that were directly observed: the presence of wet feces, a worn path from the house to the latrine, the absence of a spider web at the front part of latrine, and the presence of odor.

We analyzed village-level coverage of improved water, sanitation, and hygiene practices as categorical variables for the primary analysis, not as continuous variables, because herd protection was expected to occur when the coverage exceeded a certain threshold level, based on previous studies in the literature.[23] When designing the study protocol, we set the threshold of high coverage at 66% referring to a previous trial.[37] In this study, we adjusted the threshold to 50% in terms of a study-improved latrine and 70% in terms of improved latrine according to the JMP definition (JMP-improved latrine) because only a few clusters reached 70% or above at 10 months of follow-up in terms of operational definition of a study-improved latrine in this study. In what follows, "study-improved latrine" refers to the operational definition of an improved latrine in this study, and "JMP-improved latrine" refers to the improved latrine according to JMP criteria. For drinking water and handwashing practices, we also set the threshold at 70% referring to previous studies.[23]

Herd protection

To measure herd protection, we followed the framework proposed by Halloran and colleagues.[50] The direct effect is described as the relative reduction in disease of village members who directly received an intervention compared with those who did not receive the intervention. In their study, the direct effect is denoted by D_i/D_0, where D_i represents the risk of diarrhea in children in households that took up improved sanitation, and D_0 represents the risk in those without an improved latrine. Herd protection is denoted by D_{0_high}/D_{0_low}, where D_{0_high} represents the risk of diarrhea in the children in households without improved latrine in high-coverage communities, and D_{0_low} represents the risk in those without an improved latrine in low-coverage communities. We separated D_0 into D_{un} and $D_{no,}$ where D_{un} represents the risk of diarrhea in children in households that took up a latrine, but not an improved one, and D_{no} represents the risk of diarrhea in those without any type of latrine. We analyzed both D_{0_high}/D_{0_low} and D_{un_high}/D_{un_low}. We could not analyze D_{no_high}/D_{no_low} because there were too few households without any latrines in high-coverage communities (Figure 1).

For assessing direct and indirect effect (herd protection), we used generalized estimating equations to explore a population-averaged effect. For assessing herd protection, we maintained those with an unimproved latrine in the dataset while dropping all other subjects and estimated the effect of high coverage in the marginal model. By doing so, we could compare two children with an unimproved latrine, one living in a community of high coverage and the other of low coverage, according to the thresholds reported above. The same methods were applied also for assessing the direct effect. Exchangeable covariance matrix, log link, and robust standard errors were used for the generalized estimating equations. We adjusted for the key confounding factors including child age and sex, the presence of improved water for drinking, and appropriate handwashing at four critical times (before preparing food, after defecating, before feeding a child, and after cleaning a child's buttocks).

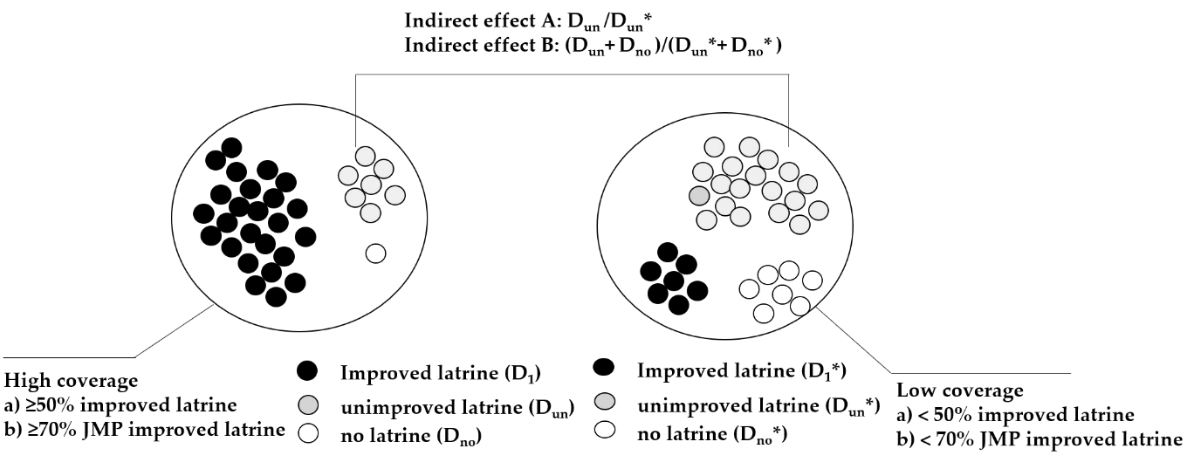

Figure 1. Indirect effect of improved latrines

Multi-level modeling of the coverage effect

To further understand the herd protection offered by village-level coverage, multilevel logistic regression analysis was applied, in which repeat observations of the same individual (survey time) were the first level, individuals were the second level, and villages were the third level. We fitted six different models. Model 1 (level 1 with only time variable) was used as the baseline model to decompose the total variance of diarrhea between the individual and village level. This was selected as the baseline model because an intercept-only model (null model) overestimates the variance at the occasion level and underestimates the variance at the subject level.[51]

Model 2 contained only individual-level factors, whereas model 3 only included village-level variables. We extended these single-level factors to form models 4, 5 and 6 by accommodating individual- and village-level variables. We estimated a fixed slope for the coefficient of an improved latrine in model 5, whereas a random slope was used in model 6.

Measures of association (fixed effects): Odds ratios were measured to assess the associations between individual-level variables and the prevalence of diarrhea with 95% confidence intervals and their p-values after adjusting for potential confounders, at both the individual and village levels.

Measures of variation (random effects): We explored random effects by assessing village-level variance, the median odds ratio (MOR), intra-cluster correlation, proportional change in variance (as a percentage), and upper and lower interval odds ratios (IORs).[52,53]

Model fitness test: The deviance, defined as -2×LN (likelihood), indicates the model fit of the data, where LN is the natural logarithm and likelihood is the value of the likelihood function at convergence. The lower the deviance, the better the model fits. In this study, all the models we compared were nested, meaning a more general model can derive a more specific model by removing some parameters. In the two nested models, the difference of the deviances follows a chi-square distribution. We performed the likelihood ratio test to explore the difference in the deviance between the two models.

We used the following equation for estimating the proportional change in community variance (PCV_C): $PCV_C = (V_{C-1} – V_{C-2})/V_{C-1}$,

where V_{C-1} is the community variance in the empty model and V_{C-2} is the community variance in another model. For example, comparing model 1 with model 2, if PCV_C is 0.3, then 30% of the community variance in the empty model is attributable to the community factors considered.[52,53]

Ethical considerations

We obtained ethical approval from the National Research Ethics Review Committee of the Ethiopian Government (NRERC 3.10/032/2015; July 29, 2015). This trial was registered as an ISRCT (ISRCTN82492848, March 13, 2015). Informed consent for enrollment was obtained from caregivers in written form.

Results

Table 1 provides both the individual characteristics of household members who participated in this study over one year and details on village-wide coverage of improved water, sanitation, and hygiene. At 10 months of follow-up after the CLTS triggering, 166 (19.2%) households in 48 villages had completed the construction of an improved household latrine meeting all the study criteria, and 97 (11.2%) used an improved latrine overall (due to existing ownership; based on direct observation on wet feces). Overall, the average age of the youngest under-five child (U5C) in the 906 households was 24 months (standard deviation, 16 months). Out of 906 household heads, 58% were Muslim and 37% were Christian. Farmers accounted for 80% of household head’s occupation.

The majority of household heads were Muslims and farmers. The majority of caregivers had not graduated from primary school. Only a small proportion of people (17.8%) reported they washed their hands with soap at all four critical times (after defecating, before food preparation, after cleaning child buttocks, and before feeding child) at baseline. There were 10 out of 48 villages with an improved latrine coverage of 50% or above at 10 months after the triggering. The number of households in the high-coverage group (i.e., 50% or above in terms of study-improved latrine) was 0 at baseline but reached 158 (18.3%) at 10 months. The number of villages with a high coverage level of improved water was 16 of 48 villages at baseline, and we assumed that this figure would remain unchanged because no interventions were done during the trial.

Table 3. Basic characteristics of participants (children, caregivers, and household heads) and their community

			Baseline	3 months June 2016	9 months December 2016	10 months January 2017
Individual variables	Caregivers' age		29.7 (5.6)			
	Caregivers' education	Not graduated primary school				
		5-8 grade	12.6 % (114/906)			
	Caregivers' gender	Female	98.5% (892/906)			
	Ethnicity of the household head	Guragenya	95.4% (864/906)			
	Religion of the household head	Muslim	58.3% (528/906)			
		Christian	37.3% (338/906)			
	Child's age	(months)	24.2 (15.8)			
	Child's sex	Girls	50.3% (456/906)			
	Improved water		73.5% (666/906)			
	Improved latrine		0.3% (3/906)	12.4% (102/822)	15.4% (127/824)	19.2% (166/865)
	Handwashing (4 times)		17.8% (162/906)	12.2% (100/822)	19.2% (158/824)	21.4% (185/865)
Collective variables	High coverage of improved water[a]	Household	70.6% (640/906)			
		Cluster	33.3% (16/48)			
	High coverage of study-improved [b]	Household[d]	0.0% (0/906)	6.6% (54/822)	10.6% (87/824)	18.3% (158/865)
			0.0% (0/48)	8.3% (4/48)	10.4% (5/48)	20.8% (10/48)
		Cluster	50-59%:0[e]	50-59%:2	50-59%:1	50-59%:4
			60-69%:0	60-69%:0	60-69%:1	60-69%:2
			70-79%:0	70-79%:1	70-79%:2	70-79%:3
			80-89%:0	80-89%:1	80-89%:1	80-89%:1
	High coverage of handwashing[c]	Household	0.0% (0/906)	6.7% (55/822)	5.6% (46/824)	11.1% (96/865)
		Cluster	0.0% (0/48)	8.3% (4/48)	6.3% (3/48)	12.5% (6/48)

[a] 70 % or more of improved water (piped water into dwelling, plot or yard; public tap/standpipe; tube well/borehole; protected dug well; protected spring; and rainwater)

[b] 50% or more of improved latrine (having a pit of ≥2m depth, slab of any material, drop-hole cover, wall, roof, door, and handwashing facilities (water and soap observed))

[c] 70% or more (washing hands at before preparing food, after defecating, before feeding a child, and after cleaning a child's buttocks)

[d] households in the villages of high coverage of a study-improved latrine

[e] number of villages in each category of coverage

Table 2 shows that children living in households with access to a study-improved latrine were less likely to contract diarrhea than their counterparts with a study-unimproved latrine. The U5C in households with a study-improved latrine had an over 50% lower odds of contracting diarrhea than those living in households with a study-unimproved latrine adjusting for child age and sex, the presence of improved water for drinking, and appropriate handwashing at four critical times (adjusted odds ratio [aOR]=0.46, 95% confidence interval [CI]=0.27–0.81, p=0.006). The aOR of contracting diarrhea among children living in households with a study-unimproved latrine compared with those without any latrine indicated a smaller reduction in the odds (aOR=0.76, 95% CI=0.40–1.44, p=0.40). Table S1 shows that the odds of having diarrhea among those with a JMP improved latrine were not significantly different from those with a JMP-unimproved latrines that did not meet the criteria of improved latrine based on JMP definition (OR=0.99, 95% CI=0.56–1.79, p=0.99).

As shown in Table 3, study-improved latrines also showed better performance for the transmission pathway of fecal-oral contamination. The odds of presence of flies around the pit-hole were much smaller in study-improved latrines than in study-unimproved latrines, and the same was true for the presence of feces around the pit-hole. Compared to poorly constructed latrines, better latrines showed lower odds of the presence of feces and flies around the pit-hole (aOR= 0.50, 95% CI=0.33–0.75, p=0.001; aOR= 0.05, 95% CI=0.03–0.10, p<0.001, respectively). For latrine use, we detected no significant difference between those who had a study-improved latrine and those who did not regarding the four proxy indicators (Table 4).

Table 2. Performance of latrines on child diarrheal prevalence by type

		Absence of latrine	Presence of latrine, but not a study-unimproved one (a)		Presence of a study-improved latrine (b)	
			unadjusted	**adjusted**	**unadjusted**	**adjusted**
All[c]	**OR**	**1.0**	**0.73**	**0.76**	**0.46**	**0.46**
	95% CI	**-**	**0.39-1.39**	**0.40-1.44**	**0.26-0.80**	**0.27-0.81**
	p-value	**-**	**0.34**	**0.40**	**0.006**	**0.006**
June (3 months)	n/N	10/57	100/663	100/663	8/102	8/102
	%	17.54%	15.08%	15.08%	7.84%	7.84%
	OR	1.0	0.91	1.33	0.27	0.26
	95% CI	-	0.19-4.29	0.26-6.79	0.05-1.32	0.04-1.51
	p-value	-	0.91	0.73	0.11	0.13
December (9 months)	n/N	9/42	76/655	76/655	8/127	8/127
	%	21.43%	11.60%	11.60%	6.30%	6.30%
	OR	1.0	0.23	0.20	0.50	-
	95% CI	-	0.02-2.36	0.02-2.18	0.03-8.83	-
	p-value	-	0.22	0.19	0.64	-
January (10 months)	n/N	7/41	62/658	62/658	7/166	7/166
	%	17.07%	9.42%	9.42%	4.22%	4.22%
	OR	1.0	0.66	0.68	-	-
	95% CI	-	0.22-1.95	0.24-1.95	-	-
	p-value	-	0.45	0.48	-	-

a Reference: absence of latrine (adjusted for individual variables: child's age and sex, presence of an improved water source, handwashing behavior at four critical times)
b Reference: presence of a latrine but not a study-improved one (adjusted for individual variables: child's age and sex, presence of improved water source, handwashing behavior at four critical times)

[c] All the data of June, December, and January were pooled. Blanks in the crude and adjusted analysis: the regression model did not converge.

Table 3. Performance of latrines on transmission pathways by type

		Presence of feces around pit-hole		Presence of flies around pit-hole		Number of flies	
		Presence of latrine, but study-unimproved one	A study-improved latrine	Presence of latrine, but study-unimproved one	A study-improved latrine	Presence of latrine, but study-unimproved one	A study-improved latrine
All	**OR**	**1.0 (reference)**	**0.50**	**1.0 (reference)**	**0.05**	**reference**	**-0.35**
	95% CI	**-**	**0.33-0.75**	**-**	**0.03-0.10**	**-**	**-0.40, -0.29**
	p-value	**-**	**0.001**	**-**	**<0.001**	**-**	**<0.001**
June (3 months)	n/N	241/660	27/102				
	%	36.5%	26.5%				
	OR		0.60				
	95% CI		0.04-8.67				
	p-value		0.71				
December (9 months)	n/N; mean(sd)[a]	153/655	19/127	545/653	61/126	10.6(0.6)	2.1(0.4)
	%	23.4%	19.0%	83.5%	48.4%		
	OR		0.45		0.05		-0.34
	95% CI		0.16-1.24		0.01.-0.30		-0.42, -0.27
	p-value		0.12		0.001		<0.001
January (10 months)	n/N; mean(sd)	149/658	14/166	546/658	54/166	6.9(0.3)	1.5(0.3)
	%	22.6%	8.4%	83.0%	32.5%		
	OR		0.25		0.16		-0.41
	95% CI		0.06-0.94		0.11-0.23		-0.49, -0.34
	p-value		0.04		<0.001		<0.001

[a] Mean (sd: standard deviation) for the column of number of flies, Blanks in some column in June: flies were not counted.

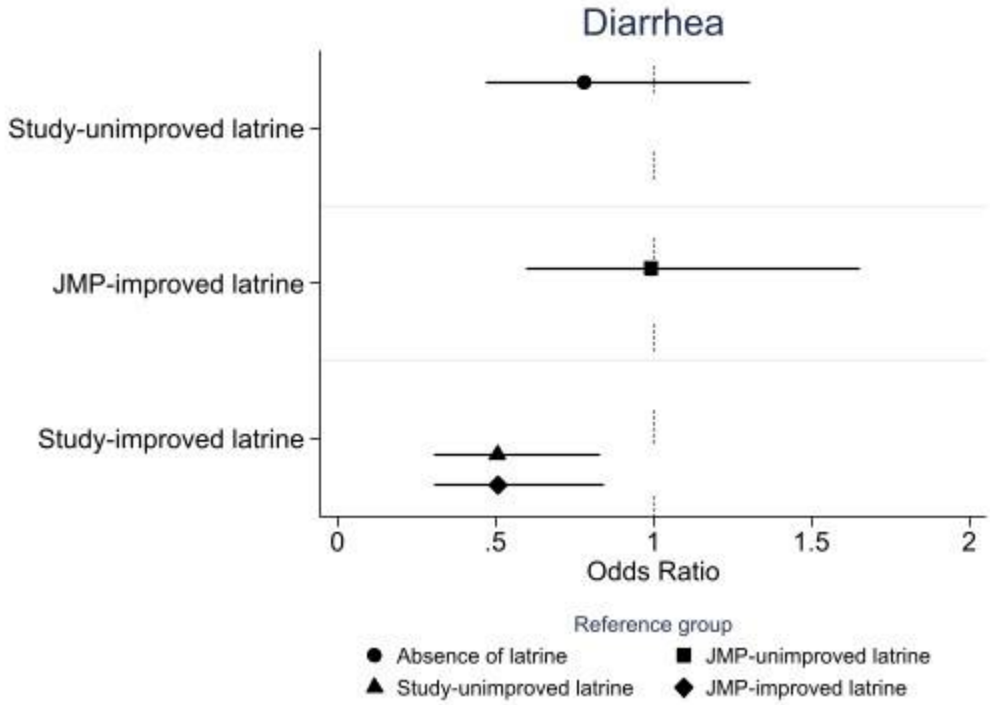

Figure 1. Performance of a latrine on child diarrheal prevalence by type (This figure indicates the performance of latrine in terms of odds ratio of having diarrhea among children living in a household with different type of latrine, y-axis: latrine type, JMP improved latrine: a pit latrine with a slab; an improved latrine (study-improved): having a pit of ≥2m depth, slab of any material, drop-hole cover, wall, roof, door, and handwashing facilities (water and soap observed); Study- unimproved latrine: unimproved latrine based on the study definition; JMP-unimproved latrine: unimproved latrine based on JMP definition. Legend in the figure indicates the reference group in each comparison.)

Table 4. Latrine use by type of latrine

		Wet feces		No spider web		Worn path		Odor[a]	
		Presence of latrine, but study-unimproved one	Presence of a study-improved latrine	Presence of latrine, but study-unimproved one	Presence of a study-improved latrine	Presence of latrine, but study-unimproved one	Presence of a study-improved latrine	Presence of latrine, but study-unimproved one	Presence of a study-improved latrine
June (3 months)	n/N	300/663	59/102	300/663	59/102	300/663	59/102		
	%	45.3%	57.8%	45.3%	57.8%	45.3%	57.8%		
	OR		1.07		1.06		1.07		
	95% CI		0.53-2.15		0.53-2.15		0.53-2.16		
	p-value		0.85		0.85		0.85		
December (9 months)	n/N	421/655	87/127	429/655	80/127	555/655	106/127	461/655	83/127
	%	64.3%	68.5%	65.5%	63.0%	84.7%	83.5%	70.4%	65.4%
	OR		1.22		0.56		0.84		0.76
	95% CI		0.38-3.96		0.21-1.54		0.33-2.13		0.15-3.76
	p-value		0.74		0.27		0.71		0.74
January (10 months)	n/N	416/658	97/166	518/658	98/166	611/658	113/166	561/658	104/166
	%	63.2%	58.4%	78.7%	59.6%	92.9%	68.1%	85.3%	62.7%
	OR		1.52		0.47		0.55		0.39
	95% CI		0.61-3.78		0.16-1.42		0.11-2.77		0.14-1.07
	p-value		0.36		0.18		0.47		0.07

[a] Odor was not measured in June

We divided the 48 villages into high-coverage and low-coverage groups. Table 5 shows the magnitude of the indirect effect (herd protection) and direct effect of a study-improved latrine. Of the children living in households without a latrine or with a study-unimproved latrine, those in the high-coverage villages (70% or more coverage of a JMP improved latrine) were less likely to contract diarrhea than those in low-coverage villages (aOR=0.55; 95% CI=0.35–0.86, p=0.008).

The odds of contracting diarrhea among children who lived in a household with a study-improved latrine in high-coverage areas were 67% lower than those of children who lived in a household with a study-unimproved latrine in a low-coverage area (aOR=0.33, 95% CI=0.14–0.79, p=0.01).

We found similar pattern for direct and indirect effects when we changed the definition of high-coverage areas to "communities with the coverage of 50% or above in terms of study-improved latrine" although we found no statistical difference (Table S2).

Table 6 shows the analysis results of multilevel models. Based on the model fit test, the model containing both individual- and village-level variables had the best fit, and the model 6 with a random slope for an improved latrine was finally selected. Based on the results of fixed effects, when comparing two children with similar predicted risk, one living in a community of higher latrine coverage and the other of lower coverage, the odds of having diarrhoea was decreased by 62% for the former (95% CI, 6%-84%). However, this model could explain only 7% of the variance in diarrhea in the baseline model at the cluster level (proportional change in variance of model 6 compared with model 1), and the IOR-80% for diarrhea was large, from 0.34 to 6.22. According to the results in the random effects, when comparing the odds of 2 randomly chosen children having diarrhea (1 from a high-coverage community and the other from a low-coverage community), the middle 80% of the odds ratio will lie between 0.34 and 6.22. The MOR quantifying the variation between communities by comparing 2 persons from 2 randomly chosen, different communities was 2.14, suggesting there are considerable between-community variations.

Table 5. Comparison of performance between study-unimproved/no latrine in high- and low-coverage areas, and study-improved latrines in high-coverage areas and study-unimproved/no latrines in low-coverage areas (based on 70% coverage of JMP improved latrine)

		Low coverage		High coverage			Comparison of **study-unimproved/no latrine** in **high- and low-coverage areas (herd protection)**			Comparison of **study-improved latrine in high-coverage areas** and all others (**study-unimproved or no latrine in low-coverage areas)**		
		Absence of a latrine	Presence of a latrine, but not an improved one	Absence of a latrine	Presence of a latrine; but not an improved one	Improved latrine	OR	95% CI	p-value	OR	95% CI	p-value
All							0.55	0.35-0.86	0.008	0.33	0.14-0.79	0.01
June	n/N	8/39	55/312	2/18	45/351	7/78	0.68	0.44-1.04	0.08	0.58	0.28-1.19	0.14
(3 months)	%	20.5%	17.6%	11.1%	12.8%	9.0%						
December	n/N	4/11	3/20	5/31	73/635	8/127	0.68	0.29-1.60	0.37	0.27	0.09-0.78	0.02
(9 months)	%	36.4%	15.0%	16.1%	11.5%	6.3%						
January	n/N	3/6	3/13	4/35	59/645	7/166	0.40	00.26-0.62	<0.001	0.22	0.06-0.85	0.03
(10 months)	%	50.0%	23.1%	11.4%	9.1%	4.2%						

Table 6. Results of multi-level analysis

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Fixed parts	Empty model	Individual-level variables	Community-level variables	Individual and community-level fixed slope	Individual and community-level fixed slope	Individual and community-level random slope
Predictor						
Intercept	0.13(0.08-0.22)	0.48(0.18-1.28)	0.19(0.09-0.41)	0.47(0.18-1.25)	0.60(0.20-1.77)	0.36(0.17-1.23)
Time	0.81(0.73-0.91)	0.81(0.73-0.91)	0.84(0.75-0.94)	0.67(0.55-0.81)	0.67(0.55-0.82)	0.67(0.5-0.81)
Study-improved latrine		0.48(0.27-0.83)		0.60(0.33-1.07)	0.60(0.33-1.08)	0.40(0.15-1.13)
Improved water		0.88(0.55-1.41)		0.87(0.54-1.40)	0.95(0.58-1.56)	0.85(0.52-1.38)
Handwashing		1.03(0.63-1.69)		1.05(0.64-1.72)	1.11(0.64-1.91)	1.06(0.63-1.75)
Child's sex		1.41(0.89-2.25)		1.44(0.90-2.29)	1.45(0.91-2.31)	1.47(0.91-2.36)
Child's age		0.97(0.96-0.99)		0.97(0.96-0.99)	0.97(0.96-0.99)	0.97(0.96-0.99)
Coverage of study-improved latrines			0.43(0.19-0.98)	0.43(0.19-0.97)	0.43(0.19-0.98)	0.38(0.16-0.94)
Coverage of improved water			-	0.67(0.31-1.42)	-	-
Coverage of handwashing			-	0.90(0.46-1.75)	-	-
Random parts						
Cluster-level variance	0.86(0.15)	0.82(0.14)	0.79(0.14)	0.79(0.14)	0.80(0.14)	0.80(0.14)
Individual-level variance	1.16(0.16)	1.06(0.16)	1.18(0.16)	1.07(0.16)	1.07(0.16)	1.12(0.17)
ICC-VPC[a]	0.18 (ICC)	0.17 (ICC)	0.16 (VPC)	0.43 (VPC)	0.43 (VPC)	0.42 (VPC)
Explained variation	Ref	4.7%	8.1%	9.3%	7.0%	7.0%

	(cluster)					
(i.e. PCV[b] in %) proportional change in variance by the new model	Ref (individual)	8.6%	-	8.6%	7.8%	3.8%
Deviance[c]	1667.4	1644.6	1657.5	1639.1	1640.3	1635.1
Model fit test results[d] (chi-square (p-value))	-	22.81 (p<0.001)	-	5.52 (p=0.14)	4.28(p=0.04)	5.22 (p=0.02)
MOR[e]	2.26	2.18	2.12	2.12	2.17	2.14
IOR[f] upper			6.42	6.42	6.54	6.22
IOR lower			0.37	0.37	0.36	0.34

[a] ICC: intra-cluster correlation, VPC: variance partition coefficient; [b] PCV: proportional change in variance; [c] The deviance : –2 × ln (likelihood), where likelihood is the value of the likelihood function at convergence, and ln is the natural logarithm ; [d] the likelihood ratio test (Model 4 of lower deviance was compared with Model 2 of larger value, which was not significantly different (p=0.14). Model 5 of lower deviance was compared with Model 2 of larger deviance, which was significantly different (p=0.04). Model 6 has the lowest value of deviance was compared with Model 5, which was significantly different (p=0.02). Hence, we finally selected Model 6.; [e] MOR: median odds ratio; [f] IOR: interval odds ratio.

Discussion

This study suggests that children living in households with a study-improved latrine were less likely to have diarrhea than those with study-unimproved latrine and those with JMP improved latrine. In addition, study-improved latrines had herd-protective effects when the level of coverage was high (study-improved latrine coverage was 50% or more). Children living in a household without a latrine or with a study-unimproved latrine in a village with high coverage were less likely to contract diarrhea than those without a latrine or with a study-unimproved latrine in a village with low coverage. The two attributes most commonly missing from JMP improved latrines that prevented them being categorised as "study-improved" were drop-hole cover and pit-depth at 10 months (Table S3).

Around 5 months after the intervention, heavy floods caused many latrines to collapse. The coverage of partially improved latrines with a latrine having a pit, pit hole cover, and slab decreased in intervention communities compared to 3 months (52% vs 55%), while it increased in the control group (35% vs 13%). This may have contributed to the lack of effect particularly at 5 months after the intervention.

The coverage of study-improved latrines increased at both 9 months (35%) and 10 months (35%) compared to 3 months (27%). The difference in study-improved latrine coverage between the intervention and control groups was 25%, 30%, and 32% at 3, 9 and 10 months, respectively. It is possible that the study-improved latrine coverage would have been higher without the heavy floods, which may have allowed us to detect a significant effect of the sanitation intervention at 5, 9 and 10 months

Latrine use was not substantially different between members of households with a study-improved and study-unimproved latrine based on direct observations. In this regard, a possible explanation for the lower odds of contracting diarrhea among children living in a household with a study-improved latrine than in those living in a household with a study-unimproved latrine could be a reduction in the chances of direct contact with feces via hands or feet, or indirect contact via flies inside or around the latrine due to the improved status of a latrine, rather than increased latrine use. We found that the odds of feces or fly presence around the pit-hole were consistently lower in study-improved latrines than in study-unimproved latrines. Similarly, the number of flies was also lower in study-improved latrines than in study-unimproved ones.

The importance of an improved latrine, even relative to other types of pit latrines, has been highlighted in several studies.[1,22] The finding that study-improved latrines had more health benefits than study-unimproved latrines in the category of pit latrines is consistent with a previous study done in the Democratic Republic of Congo.[54] Nakagiri and colleagues investigated the association between diarrhea and each specific component of a latrine, such as the pit depth, slab, pit-hole cover, and wall.[22] According to their study, pit depth and the presence of a slab were significantly associated with diarrhea reduction by directly disrupting fecal-oral transmission. The herd-protective effect of the sanitation intervention was consistent with previous simulation modeling studies.[23]

We could not overcome the typical limitations of the 7-day period prevalence of diarrhea ascertainment solely based on caregivers' reports, which entails several biases such as reporting bias, recall bias, and social desirability bias.

For latrine use, we used observation results using four different proxy indicators; however, we cannot rule out the possibility that the four different proxy indicators may not fully represent their actual use of latrine. Further research is needed to determine to what extent these indicators adequately represent the actual use of latrines.

Measuring latrine use continues to be a challenge. Efforts to use electronic motion sensors have shown promise in a study in Orissa, but implementation is costly.[55] A low-cost measurement method of assessing latrine use needs to be developed to be employed at a large scale and a lower cost, for example by using survey tools that camouflage the true purpose of a study measuring latrine use.[56]

The fact that we could not detect significant differences in four distinct indicators of latrine use indicates that the possible explanation for the better health benefits of a study-improved lies in the improved status of the latrine structure rather than in increased household latrine use alone.

In this study, we used IOR and MOR because the usual odds ratio interpretation is incorrect for quantifying associations between variables varying on the cluster level and outcomes in individual level. The variable of interest, community-level coverage, does not vary between individuals within-community, and we thus have to compare persons with different random effects. The IOR indicates the interval that 80 percent of odds ratios of having diarrhea lie between randomly chosen two children with identical individual covariates, one from a high-coverage and the other from a low-coverage village. The interval contains 1, suggesting that the effect of coverage is small compared to the cluster variability. The MOR quantifies the variation between villages by comparing two children with the same covariates from two randomly chosen, different villages. The MOR in this study was 2.14, which suggests that if a child moves to another village with a higher probability of having diarrhea, the risk of contracting diarrhea will increase 2.14 times. The final model in the multi-level regression analysis explained only small percentage of the variance in diarrhea at the village level. This points to the fact that there is still a large unexplained variance in child diarrhea at village level in our final model. We could not measure water quality, and handwashing behavior was based on self-report. We infer that the unexplained variance at village level might have been reduced if we could have included properly measured coverage of water quality and handwashing behavior. If the coverage of a study-improved latrine reached a universal coverage, we may have been able to explain more variance of child diarrhea at village level.

We excluded coverage of improved water and handwashing in the final model based on the model fit test results. Caution is needed when interpreting the final model with no context variables of water and handwashing. This study may not suggest that water and handwashing coverage does not matter. The reason that the final model does not include water and handwashing coverage may probably lie in measurement method of water and handwashing. We could not measure the coverage of clean water based on water quality at the point of use. In addition, we relied on respondent’s self-report for handwashing behavior instead of direct observation. If we had measured coverage of clean water based on water quality at the point of use, and observed handwashing behavior instead of relying on interviewee’s recall to estimate coverage of handwashing, the final model might have included community-level water and handwashing behavior coverage.

It is worth noting that this is an empirical study demonstrating the existence of herd protection from a sanitation intervention, confirming the importance of reaching universal coverage for water, sanitation, and hygiene.

We assumed that improved water coverage remained same as the observation period after CLTS triggering in the trial was only 10 months and also there was no water project in the study area. However, we could not rule out any possibility that it could get better or worse, which was not reflected in our study.

For confounding variables in the adjusted analysis, we referred to previous studies[57,58] that modeled risk categories to predict child diarrhea, which suggested that socio-economic characteristics affect diarrhea indirectly via water, sanitation/environment, and hygiene/food. We controlled for child age, sex, water and handwashing behaviors in the adjusted analysis but we could not include food hygiene and childcare-related variables due to absence of data, which is a limitation of this study.

We believe that this study has policy implications in terms of advocating for achieving universal health coverage of water, sanitation, and hygiene. This study also suggests that the potential of improved sanitation in many existing studies may have been frequently underestimated because the quality was poor and the coverage, particularly of improved latrines, was low or did not reach a sufficient level in many trials.[59-62]

We recommend that academic studies and routine monitoring and evaluation programmes should measure more latrine characteristics and compare multiple latrine categories instead of just binary comparisons.

The definition of an "improved latrine" should be revisited at least in the research domain, with a focus on gathering more substantial evidence through rigorous investigation. This is to ascertain whether sanitation facility can effectively contain faeces to prevent fecal contamination. The redefinition should place greater emphasis on the latrine's performance or functionality in interrupting transmission. Consequently, some latrines currently classified as "improved latrines" might need to be reclassified as "unimproved".

In numerous sanitation interventions, particularly those involving CLTS, the importance of latrine quality appears to have been neglected. Up until now, the emphasis on latrine quality or design has not been adequately addressed. In fact, one of the key principles in the conventional CLTS approach is not to make suggestions regarding the latrine design. Dr. Kamar Kar, the founder of CLTS, argued that placing emphasis on latrine design could lead to issues of inequality. He suggested that the most vulnerable individuals within a community could become further marginalized due to their difficulty in accessing higher quality latrines.[63] His concern is understandable, as superior latrine facilities might incur costs that these vulnerable individuals are unable to afford. However, if community members are unable to reap the benefits of a latrine, it is uncertain whether they would be motivated to continue their climb up the sanitation ladder. Instead, one could deduce that if they experience no advantages from using a latrine, they might revert to their previous practices of open defecation.[64]

Patil et al. argued that sanitation remains beneficial, even if it does not have a direct effect on health, due to its other social benefits, which might imply that the quality of the latrine is of lesser importance.[60] Ross et al. reported that a sanitation intervention increased quality of life in low-income setting.[65] This claim warrants further empirical research in different settings to confirm whether the proposed social benefits extend to low quality latrines deemed sufficient in many CLTS interventions.

We need to find better ways to roll out sanitation interventions that are able to deliver high quality toilets, which interventions focusing on behaviour change seem unable to do.

Humphrey et al. advocated new and innovative interventions "that are less dependent on behaviour change and more efficacious in reducing faecal exposure—a paradigm shift away from how rural WASH programmes are delivered".[66] We may need a rethinking of current sanitation interventions, which emphasize behavior change, and instead seek an appropriate approach towards achieving universal sanitation coverage, given its low compliance rate.

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Author contributions: SC and SJ conceived and designed the study; SJ, TA and DBB coordinated the data collection; SC developed the data analysis plan; SJ, TA and DBB contributed to project administration; SC and YJ analyzed the data and interpreted the results; TA and ET contributed to data curation; SC wrote the first draft; W-PS and IR contributed importantly to the theoretical and practical considerations of the analysis and interpretation; All authors reviewed, critically revised, and approved the final version of this manuscript before submission.

Disclaimer: NA

Competing interests: None declared.

Supplementary Materials: Table S1. Performance of latrines on child diarrheal prevalence by type; Table S2. Comparison of performance between unimproved latrines in high- and low-coverage areas, and improved latrines in high-coverage areas and unimproved latrines in low-coverage areas (based on the coverage 50%of an improved latrine coverage); Table S3. Detailed status of JMP improved latrines (% with the following component).

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Chapter 6. Costs and benefits of a community-led total sanitation intervention

The following research paper addresses research objective 3): estimate the costs, benefits, and effectiveness of the CLTS intervention. This chapter presents the economic efficiency of the community-led total sanitation intervention. In this study, the costs and benefits of CLTS are analysed.

RESEARCH PAPER COVER SHEET

Please note that a cover sheet must be completed for each research paper included within a thesis.

SECTION A-Student Details

Student ID Number	Lsh157351	**Title**	Dr.
First Name(s)	Seungman		
Surname/Family Name	Cha		
Thesis Title	Evaluation of a community-led total sanitation intervention in a rural area of the Southern Nations, Nationalities, and Peoples' Region, Ethiopia		
Primary Supervisor	Wolf Schmidt		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

SECTION B-Paper already published

Where was the work published?	International Journal of Environmental Research and Public Health		
When was the work published?	14 July 2020		
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion.			
Have you retained the copyright for the work?*	No	Was the work subject to academic peer review?	Yes

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SECTION D-Multi-authored work

For multi-authored work, give details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	**S.C.,** S.J., Y.A.D. and J.S. conceptualized the study. **S.C.,** S.J., D.B.B. and T.A. implemented the trial. **S.C.** conducted the statistical analysis and wrote the draft of the manuscript under the guidance of IR.

SECTION E

Student Signature	
Date	**18/12/23**

Supervisor Signature	
Date	**2/1/24**

Benefits and costs of a Community-Led Total Sanitation intervention in rural Ethiopia – a trial-based ex post economic evaluation

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Abstract

We estimated the costs and benefits of a community-led total sanitation (CLTS) intervention using the empirical results from a cluster-randomized controlled trial in rural Ethiopia. We modelled benefits and costs of the intervention over 10 years, as compared to an existing local government program. Health benefits were estimated as the value of averted mortality due to diarrheal disease and the cost of illness arising from averted diarrheal morbidity. We also estimated the value of time savings from avoided open defecation and use of neighbors' latrines. Intervention delivery costs were estimated top-down based on financial records, while recurrent costs were estimated bottom-up from trial data. We explored methodological and parameter uncertainty using one-way and probabilistic sensitivity analyses. Avoided mortality accounted for 58% of total benefits, followed by time savings from increased access to household latrines. The base case benefit-cost ratio was 3.7 (95% CI: 1.9 - 5.4) and the net present value was Int'l$1,193,786 (95% CI: 406,017 - 1,977,960). The sources of the largest uncertainty in one-way sensitivity analyses were the effect of the CLTS intervention and the assumed lifespan of an improved latrine. Our results suggest that CLTS interventions can yield favorable economic returns in the right conditions.

Keywords: cost-benefit analysis, community-led total sanitation, Ethiopia, sanitation improvements, household latrine

1. Introduction

Universal access to safely managed sanitation is one of the sustainable development goal targets [1,2]. However, progress has been slow in sub-Saharan Africa, where access to safely managed sanitation services expanded from 15% to 18% between 2000 and 2017 [2]. By contrast, it increased from 32% to 64% in South Eastern Asia [2].

The community-led total sanitation (CLTS) approach was initiated in Bangladesh in 2000 [3]. It attempts to motivate behavior change by triggering a collective sense of disgust about open defecation [4]. A core principle of CLTS is not to provide subsidies for latrine construction, but there has been debate about whether to provide subsidies to the poorest and most marginalized [5,6]. CLTS was also criticized as promoting unimproved latrines, and a recent study suggested that unimproved latrines may lead to reversion to open defecation [7, 8]. In response to these critics, the CLTS approach has evolved, sometimes now implemented in combination with sanitation marketing or subsidies to the poorest households [6]. More than 30 countries have adopted CLTS as a national sanitation policy, including Ethiopia [6]. After a pilot sanitation program with a community-led approach in 2007, the Ethiopian government developed a set of guidelines and verification protocols, adding a hygiene component in 2008 (called CLTSH) [9].

Economic evaluations inform investment decisions by comparing costs and outcomes of investment options [10]. Understanding the benefits and costs of sanitation interventions can help make informed decisions about resource allocation, in particular in identifying settings where there is high likelihood of a net benefit [11].

According to a recent review of the knowledge base for sanitation interventions, most cost-benefit analyses (CBAs) were identified as presenting global-level and/or ex-ante analyses, relying heavily on assumptions for parameter values [12]. The authors suggested that more ex-post CBA studies using empirical data from interventions settings to inform model parameters are required. Other studies have also emphasized that costs and benefits can be highly context-specific, arguing for more empirical studies [13-16]. The few existing ex-post studies do not present tables of parameter values, or equations setting out how they calculated costs and benefits, precluding transparency and replication [17-19].

Radin and colleagues argued that the benefits of CLTS interventions in prior studies had been overestimated largely because the time commitment of community members mobilized for the intervention was not taken into account [16]. Their base case benefit-cost ratio (BCR) was 1.7 for medium-uptake village. They found that, while net present value was positive in 75% of the trials for sensitivity analysis, CLTS would not be attractive compared to the interventions in other sectors [16].

However, their estimation was done on a hypothetical basis, rather than using model parameters informed by primary data collection. Given these recent reviews' and studies' emphasis on the need for more ex-post and empirical CBA studies, we designed the present study. We aim to estimate the costs and benefits of a CLTS intervention using the empirical results from a cluster-randomized controlled trial of a CLTS intervention in rural areas of Ethiopia. To our knowledge, this is the first CBA of a CLTS intervention based on actual implementation in a given context [20]. For transparency, we present detailed parameter tables and equations demonstrating how costs and benefits were calculated.

2. Materials and Methods

2.1. Study area

This cost-benefit analysis (CBA) took place alongside a randomized trial, the protocol and results of which are reported elsewhere [21, 22]. The intervention took place in the Southern Nations, Nationalities, and Peoples' Region (SNNPR), a state in south-western Ethiopia, specifically in the Cheha and the Enemor Ena Ener woredas (districts). The total population of these predominantly rural districts was 133,233 and 204,937, respectively, in 2014 [23]. Intervention delivery took place in 212 gotts (villages) distributed across all kebeles (sub-districts) within those districts, of which 48 gotts were included in the trial. The majority of the population (64%) are Muslim and 33% are Ethiopian Orthodox [23]. Trial baseline data revealed that approximately three quarters of the population in study villages owned latrines, but that most of these were low-quality unimproved pit latrines (Figure 1).

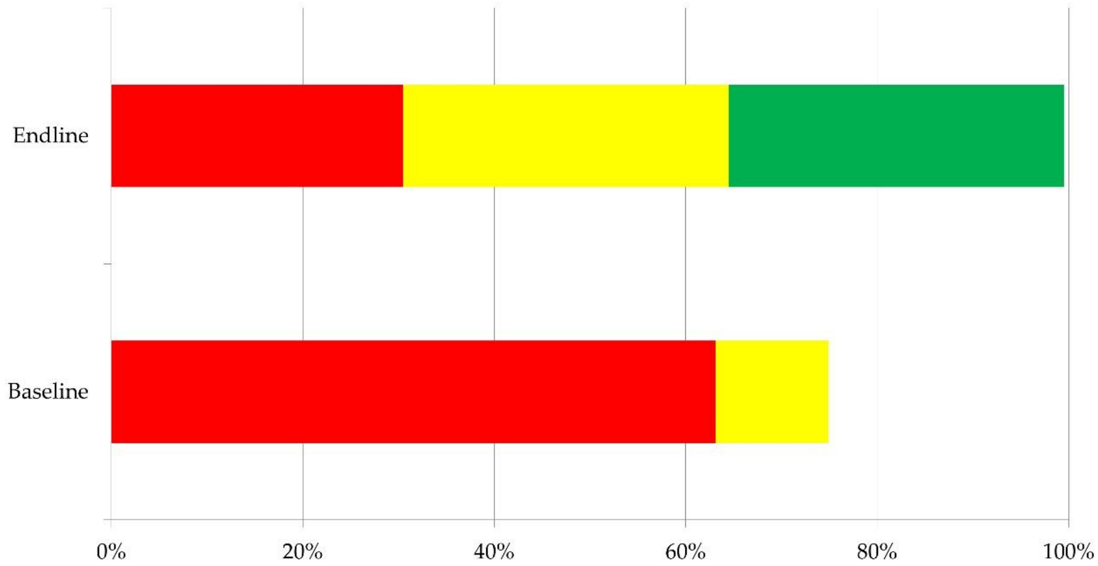

Figure 1. Sanitation coverage by latrine type (red color: simple pit latrine; yellow color: partially improved latrine; green color: improved latrine, an improved latrine: equipped with pit 2-meter deep or more, pit-hole cover, slab, wall, roof, door and hand-washing facility with soap; partially improved latrine: not an improved latrine but equipped with at least pit, pit-hole cover, and slab; simple pit latrine: all the other latrines not included in an improved or partially improved latrine)

2.2. Intervention

For the randomized trial, a 'phase-in' design was adopted [24]. In the first phase, 24 randomly sampled villages within the two districts received a CLTS intervention between February 2016 and January 2017. The other 24 served as a control group in which nothing was done beyond health extension workers (HEWs) continuing their usual activities which did not include substantial sanitation-related work (discussed in Supplementary Text (Text S1). In the second phase from February 2017, the control villages received the same intervention. Enrolled households were followed up four times during 10 months.

CLTS was rolled out in the intervention group as follows. A group of CLTS facilitators was trained, comprising district health officials and health professionals working for health centers, as well as health extension workers (HEWs) from health posts. They undertook CLTS triggering in the 24 villages in February and March 2016. One or two CLTS promoters were recruited from every village, and they performed follow-up activities after the triggering by encouraging community members to build an improved latrine through community conversations and household visits together with CLTS facilitators. No financial or material subsidies were provided for constructing household latrines in this intervention. After the intervention, 69% of households took up a household latrine equipped with, at least, pit, pit-hole cover and slab, and 35% had an improved latrine defined as, in this study, having pit (2 meter-deep or above), pit-hole cover, slab, wall, roof, door and hand-washing facility with soap within 6 meter from the latrine (Figure 2) - full data on latrine types and characteristics are reported in main trial study, as well as more details of the setting and intervention [22]. The CLTS intervention was implemented as a sub-component of a larger project funded by the Korea International Cooperation Agency (KOICA), which included installation of gravity-fed piped water to public taps. Since water systems were installed after the CLTS intervention was completed both in the intervention and control villages, the water component is of no relevance to the present analysis. We obtained ethical approval from the National Research Ethics Review Committee under the Ministry of Science and Technology, Federal Democratic Republic of Ethiopia (NRERC 3.10/032/2015; July 29, 2015) and the

London School of Hygiene & Tropical Medicine (LSHTM Ethics Ref: 16260; February 22, 2019).

Figure 2. An improved latrine (left: inside, right: outside).

2.3. Study design

Our study design comprises an estimation of the incremental costs and benefits of a CLTS intervention to “do nothing” scenario over a 10-year horizon, for the trial study population of 9,713. It does so by extrapolating data from a randomized trial in which these scenarios comprise the intervention and control groups, taking a societal perspective [10]. Details of the equations underlying the CBA model are described in Table 1. We followed reference case guidelines [25,26] and adhered to the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) [27] (Text S2). All analyses are reported in constant 2016 international dollars (int’l $).

2.4. Benefit measurements

2.4.1 Health benefits

Health benefits were estimated as the value of averted mortality due to diarrheal disease and the cost of illness arising from averted diarrheal morbidity. The ratio of longitudinal prevalence of child diarrhea between intervention and control villages was estimated. Children under 5 in the study area were reported to have 5.4 days of diarrhea in 365 days in the control group, using a novel diary method [21]. The trial identified a 29% relative reduction in the longitudinal prevalence of diarrhea in the intervention compared with the control villages, leading to 1.6 days of diarrhea averted per child per year. Further details are provided in Supplementary Table (Table S1). Unlike many previous studies [13-15], we estimated the cases averted in other age groups based on empirical data. These were 0.42 cases averted per year for the 5-14 age group and 0.33 for the group aged 15 or above (Table S1).

① Benefits from premature deaths averted

To estimate deaths averted, we multiplied the total cases averted by the case fatality rate (0.07%, 0.05%, and 0.03% for each age group, respectively) [28]. To value avoided mortality, we used the value of a statistical life (VSL) method, as recommended by a CBA reference case [26,29]. This assumes that survival of a working-age individual would yield economic returns, and surviving children would yield economic returns after they reach productive years of age. A benefit transfer approach was used to estimate the VSL for Ethiopians. VSL reflects "individuals' willingness to exchange money for a small change in their own risk (26)". The value of mortality risk reductions varies depending on the risk, individuals affected by a policy, and characteristics of society. Therefore, it should be derived from high quality studies of the people affected by a policy. In some cases, particularly in low- and middle-income countries, extrapolation from studies of other populations is conducted due to the scarcity of studies. Population-average VSL can be estimated for Ethiopia, using research conducted in high-income countries as reference values. This extrapolation can be done by using the gross national income (GNI) per capita of the two countries (ie., Ethiopia and the reference country), and income elasticity. Income elasticity is an important parameter in value transferring between high- and low- income countries, helping us estimate the change in the VSL associated with a change in income. We used a relatively higher value (i.e., 1.5) of income elasticity to estimate VSL conservatively (26). We conducted sensitivity analysis to address uncertainties.

A commonly-used VSL for the USA is Int'l $8.9 million [29], and the gross national income (GNI) per capita was Int'l $58,700 in the USA and Int'l $1,730 in Ethiopia in 2016 [30]. With an income elasticity of 1.5 [29], the VSL for Ethiopia in 2016 was estimated to be Int'l $45,194.

② Benefits from diarrhea cases avoided

Fewer cases of diarrhea occurring can bring about economic benefits by reducing the costs of health and non-health care. The proportion of caregivers seeking treatment (i.e. taking their child to a health facility, drug store, or traditional healer) when their children contracted diarrhea was assessed from trial data. The number of diarrhea cases averted was multiplied by the unit cost of diarrhea treatment from trial data. We assumed a zero benefit from reduced costs of self-treatment. Non-health-sector direct benefits relate to the reduced costs of transportation to health facilities and other resultant expenses such as meals and accommodation, which were assessed from trial data. Transportation costs to a drug store or a traditional healer were not estimated. When a child contracts diarrhea, she or he needs to receive more care from caregivers, meaning they lose productive time [14-16]. Similarly, if an adult has diarrheal disease, she or he may lose the opportunity to engage in productive work [14-16]. This time has an opportunity cost. We valued an hour of time at 50% of the average hourly income of community members aged 15 or above, and 25% for school-age children between 5 and 14 years of age [16,31]. Household income of the study population was surveyed during the trial, and the mean used to calculate the value of time, because the majority of people were not formally waged. The average hourly income of caregivers was multiplied by the total hours saved per year. We assumed 1,920 working hours per year (240 days per year: 4 weeks per month; 5 days per week; 8 hours per day). The time spent by Health Extension Workers

(HEWs) treating patients with diarrhea was valued using the same method [16,17] – see more details in Supplementary Text (Text S1).

We estimated a 2% annual income growth for the base case, which was incorporated into the calculation of the VSL and the value of time [16]. Population growth was not incorporated, to allow comparison with the latest hypothetical CBA of a CLTS intervention [16]. We thus assume consistent size of population in each age group over the time horizon. However, as part of sensitivity analysis, we ran a separate analysis taking population growth into consideration.

2.4.2. Time savings from increased accessibility to a household latrine

We estimated how many households had switched from defecating in the open, a communal latrine, or a neighbor's latrine to their own household latrine, and how much time they saved from the switch, based on trial data. These savings were monetized using the same value of time as above for all individuals aged over-5. The value of time savings was not counted for children under 5. As for the frequency of trips to an open defecation site, a communal latrine, or a neighbor's latrine prior to the intervention, we assumed six times per day for women and once a day for men based on discussions with people in the community. Male members reported mostly urinating around the household compound, while women did not.

2.5. Cost measurements

An incremental cost analysis [10] was used, in which the costs of the CLTS intervention were compared to the costs of the limited sanitation-related activities usually undertaken by HEWs (which characterizes what took place in control areas). The cost of the latter is estimated using a time and motion study of HEWs activities in Ethiopia [32]. – full details are provided in Text S1. The Ethiopian government submitted a proposal for the integrated Water, Sanitation, and Hygiene (WASH) project to KOICA in 2013 and the target areas of the project were selected among the districts that had no previous CLTS intervention [33]. The SNNPR state has been implementing CLTS in eight districts since 2009, but the Cheha and Enemor Ena Ener districts had never previously received a CLTS intervention [34].

Since we took a societal perspective, we included the value of all resources for implementing and maintaining the CLTS intervention over the horizon, and other resultant costs. We followed reference case definitions of capital and recurrent costs [26]. Data were drawn from the project's financial records and household survey results. Costs were categorized in four ways: initial investment, recurrent costs, program costs and local investments. The costs of management, training for CLTS facilitators and CLTS promoters, community education, and incentives for CLTS promoters were categorized as program costs. Local actors' and community members' time spent on CLTS activities, including latrine construction, were categorized as local investments. If people purchased materials for latrine construction, those were also categorized as local investments. A top-down approach was used to estimate the costs of the program (based on financial records), while a bottom-up approach was used to estimate the costs of local investments (based on combining resource use estimates with unit costs).

The recurrent costs of latrines included maintenance, operations, and hygiene education, which were estimated as 10% of annualized capital costs in the base case [12-16, 35]. Project financial records were audited by an independent accountant assigned by the KOICA. The time horizon for estimating costs and benefits was 10 years, the estimated average useful life of an improved latrine in this setting, modified in sensitivity analyses (Figure S1, Text S3). UNICEF estimated the lifespan of a pit latrine to be 10 years assuming a 2-meter pit depth and six members in a household [36]. Hutton estimated the lifespan of a basic latrine to be 8 years and that of a safely-managed sanitation to be 20 years [37].

2.6. Sensitivity analyses

To explore uncertainty surrounding estimates, we carried out one-way and probabilistic sensitivity analyses. The probabilistic sensitivity analyses explored parameter uncertainty. We conducted 10,000 Monte Carlo simulations, varying model parameters over a range of plausible values. The one-way analyses primarily explored methodological uncertainty around our assumptions about toilet useful life, the value of time, and the discount rate. For the value of time, a range of 25% to 75% was used for adults and 0% to 50% for school-aged children [31]. For the discount rate, 0% and 8% were used as the lower or upper bounds. For toilet useful life, we assumed 5 years and 15 years as upper and lower bounds. Finally, in the base case, we assume that intervention effects are sustained throughout the time horizon. In an alternative "slippage" scenario, we assume that reversion to pre-intervention behaviors occurs at 3.5% a year. This assumption is half the 7% observed in a study of CLTS sustainability in Ethiopia by Crocker et al. because the latrine quality achieved in our study was higher and baseline proportion of open defecation practice was low in our setting [38]. We modelled this as a 3.5% annual decrease in cases averted, costs averted and time savings. The parameter distributions for each variable in the probabilistic sensitivity analysis, the parameter range used for the one-way sensitivity analysis and its justification are described in the Supplementary Table (Table S2). We present a tornado plot for the one-way analyses, and cumulative frequency distributions for the probabilistic analyses.

Table 1. Equations for estimating costs and benefits

Benefits	
Present value of total benefits	$TB_{PV} = \sum_{t=1}^{T} \sum_{k=1}^{3} P_{tk} * B_{tk} (1+r)^{-t}$
TB_{PV}: present value of total benefits to all people in the intervention communities; **B_{tk}**: value of the benefits to each member of age group k in year t; **r**: discount rate; **P_{tk}**: number of population in age group k and year t in the intervention communities	
Value of the benefits = (a) benefits from premature deaths averted + (b) benefits from diarrhea cases avoided + (c) benefits from increased accessibility	$B_{tk} = (PDA_{tk} * VSL_t) + (DCA_{tk} * COI_{tk}) + (TS_{tk} * VOT_{tk} * HI_{tk})$
PDA_{tk}: premature deaths averted in age group k and in year t, number of deaths avoided due to the intervention's effect; **VSL_t**: value of a statistical life in year t; **DCA_{tk}**: diarrhea cases averted in age group k and in year t; **COI_{tk}**: the cost of illness in age group k and in year t; **TS_{tk}**: time savings in age group k and in year t, number of hours saved from no longer walking to an open defecation place (or a communal latrine, a neighbor's latrine) due to the intervention for each member of age group k in year t; **VOT_{tk}**: value of time for a member of age group k in year t, a fraction of the average hourly income of the people in the intervention communities; **HI_{tk}**: the average hourly income of the people in the intervention communities	
① Total premature deaths averted	$PDA_{tk} = DCA_{tk} * CFR_k$
DCA_{tk}: diarrhea cases averted in age group k and in year t; **CFR_k**: case fatality rate of diarrhea for a person in age group k	
② Benefits from diarrheal cases avoided (the cost of illness)	$COI_{tk} = P_{tk} * SMT_k * ((C_{ipk} * IP_k) + (C_{opk} * OP_k) + TP_k + M_k + (AC_k * IP_k) + (HOP_k * VOT_{tk} * HI_{tk}) + (HIP_k * VOT_{tk} * HI_{tk}) + (HOP_k * VOTHEW_t * HIHEW_t) + (HIP_k * VOTHEW_t * HIHEW_t)) + P_{tk} * (1 - SMT_k) * HNSMT_k * VOT_{tk} * HI_{tk}$
SMT_k: percentage of diarrhea cases for which individuals in age group k visit health facilities to seek medical treatment; **C_{ipk}**: cost of inpatient care; **C_{opk}**: cost of outpatient care; **IP_k**: percentage of diarrhea patients visiting health facility to seek medical treatment in age group k who receive inpatient care; **OP_k**: percentage of diarrhea patients visiting health facility to seek medical treatment in age group k who receive outpatient care; **TP_k**: transportation cost for those visiting a health facility to seek medical treatment; **M_k**: food and drinks cost for those visiting a health facility to seek medical treatment; **AC_k**: accommodation cost for those visiting health facility to seek medical treatment; **HOP_k**: number of working hours lost due to being sick or caring for a sick person in age group k for those receiving outpatient care; **HIP_k**: number of working hours lost due to being sick or caring for a sick person in age group k for those receiving inpatient care; **$VOTHEW_t$**: value of time for health extension workers in year t; **$HIHEW_t$**: the average hourly income of health extension workers in year t; **$HNSMT_k$** : number of working hours lost due to being sick in age group k for those not visiting health facilities	
③ Benefits from increased accessibility (time savings)	$TS_{tk} = \sum_{m=1}^{M} TS_m * F_k * 365$
TS_{tk}:: time savings in age group k and in year t; **TS_m**: time saved per each community member M for age group k from not walking to an open defecation site, a communal latrine, or a neighbor's latrine; **M**: number of community people who shifted from open defecation or communal latrine use to household latrine use in the intervention communities; **F_k**: number of times a person defecates or urinates per day	

Costs	
Present value of total costs	TC_{PV} = CRCP + CRCCL + $\sum_{t=1}^{T} O\&M_t(1+r)^{-t}$ + $\sum_{t=1}^{T} E_t(1+r)^{-t}$
TC_{PV}: present value of total costs = initial cost + additional cost (operation & management, and education); **CRCP**: capital cost and recurrent cost of program; **CRCCL**: capital cost and recurrent cost of community and local stakeholders' commitment; **$O\&M_t$**: operation & management cost in year t, 10% of annualized initial capital cost; **E_t**: education cost in year t, 10% of annualized initial capital cost; **capital cost items of program**: vehicles, motorcycles, and items worth more than US$100**; capital cost items of community and local government commitment**: cost for latrine construction; **recurrent cost of program**: total cost training, facilitation, management, and salary spent by the program management team; **recurrent cost of community and local stakeholders' commitment**: cost of time spent by local actors and community people (except for latrine construction)	
Annualized investment cost	E=(K-(S/(1+r)n))/A(n,r)
E: the annualized investment cost; **K**: the purchase price; **S**: the resale price (assumed to be 0); **n**: the lifespan of boreholes; **r**: the discount rate; **A(n,r)**: the annuity factor, A(n,r) = (1-(1+r)-n)/r (n years at r discount rate)	
Capital cost of latrine construction	CC=$\sum_{h=1}^{H} CCLM_h$ + ($\sum_{hh=1}^{HH} TLC_{hh}$ * $VOT_{k=3}$*HI_{03}
CC: capital cost**; $CCLM_h$**: capital cost for latrine construction materials purchased for a household h; **H**: number of households that purchased materials for construction of a household latrine; **TLC_{hh}**: time in hours spent on household latrine construction by a household hh; **HH**: number of households that constructed a household latrine; **capital cost items of program** (vehicles, motorcycles, and items worth more than US$100)=annualized cost*days of project implementation/365; **HI_{03}**: hourly income for adults at time=0	

3. Results

The base-case values for the parameters of the benefits and costs of the CLTS intervention are presented in Table 2. There were 1,737 households in the 24 intervention villages. The number of the population by age group was 1301 for under-5 children, 3,804 for children aged 5 to 14, and 4,608 for people aged 15 or above. Sixty-three percent of caregivers reported seeking health care when their child had diarrhea, and 56% took their child to a health facility and the other 3% to a drugstore or a traditional healer. The other 4% sought home-based care. Among the children with diarrhea, 5% were reported to have been hospitalized for an average of 5 days. When the children had diarrhea, they needed to receive 1 day of care from their caregivers. The proportion of open defecation declined by 3% among children aged 5-14 and 4% among people aged 15 or above, and they reported saving 9 minutes for each round trip from the switch. Twenty percent of people aged 15 or above reported switching from using a neighbor's latrine to their own household latrine, which allowed them to save 5 minutes per round trip.

Table 2. Parameter values (base case)

Age Group	Parameters	Unit	Value	Data source
Overall	Number of villages	village	24	Trial data
	Improved latrine uptake (intervention group)	%	35.0	Trial data
	Households in the intervention group	households	1,737	Trial data
	Number of children (<5)	person	1,301	Trial data
	Number of children (5-14)	person	3,804	Trial data
	Number of adults (≥15)	person	4,608	Trial data
	Discount rate	%	3	Reference [16]
	Annual income growth	%	2	Reference [30]
	VSL(Value of Statistical Life)	Int'l $	45,194	Reference [26,29,30]
	Useful life of an improved latrine	years	10	Reference [36,37]

Age Group	Parameters	Unit	Value	Data source
	Operation & Maintenance cost (proportion of annualized cost of initial investment)	%	10	Reference [35]
	Time constructing a latrine (per household)	hours	120	Trial data
	Diarrhea case fatality rate (<5)	%	0.07	Reference [27]
	Diarrhea case fatality rate (5-14)	%	0.02	Reference [27]
	Diarrhea case fatality rate (≥15)	%	0.03	Reference [27]
Children (<5)	Proportion of children with diarrhea whose caregivers sought care	%	62.8	Trial data
	Proportion of children with diarrhea taken to health facilities	%	56.1	Trial data
	Proportion seeking treatment from drug store	%	2.0%	Trial data
	Proportion seeking treatment from a traditional healer	%	1.0%	Trial data
	Proportion of health facility careseekers becoming outpatients	%	50.9	Trial data
	Proportion of health facility careseekers becoming inpatients	%	5.2	Trial data
	Average days of hospitalization (per case)	days	5.0	Trial data
	Caregiver lost days due to home care for a child with diarrhea	days	1	Trial data
	Number of diarrhea cases avoided per year (under-5 children)	cases	1.51	Trial data
	Treatment cost (health facilities)	Int'l$	0.70	Trial data
	Treatment cost (drug stores)	Int'l$	0.55	Trial data
	Treatment cost (traditional healers)	Int'l$	0.25	Trial data
	Meal cost	Int'l$	0.20	Trial data
	Transportation cost (round trip)	Int'l$	0.75	Trial data
	Accommodation cost (inpatient)	Int'l$	3.66	Trial data
Other groups (5-14 or ≥15)	Proportion of diarrhea patients whose caregivers sought care (or who sought care themselves)	%	45.40	Trial data
	Proportion of diarrhea patients taken to health facilities	%	34.69	Trial data
	Proportion seeking treatment from drug store	%	5.61	Trial data
	Proportion seeking treatment from a traditional healer	%	6.12	Trial data
	Proportion of health facility careseekers becoming outpatients	%	32.40	Trial data
	Proportion of health facility careseekers becoming inpatients	%	2.29	Trial data
	Average days of hospitalization (per case)	Days	3.50	Trial data
	Caregiver lost days due to home care for a child with diarrhea	Days	1	Trial data

Age Group	Parameters	Unit	Value	Data source
Other groups (5-14 or ≥15)	Treatment cost (health facilities)	Int'l$	0.70	Trial data
	Treatment cost (drug stores)	Int'l$	0.55	Trial data
	Treatment cost (traditional healers)	Int'l$	0.25	Trial data
	Meal	Int'l$	0.30	Trial data
	Transportation cost (round trip)	Int'l$	1.49	Trial data
	Accommodation cost	Int'l$	7.32	Trial data
	Hourly income (before application of valuation percentages)	Int'l$	0.67	Trial data
	Switched from open defecation to a household latrine (5-14)	%	2.85	Trial data
	Switched from open defecation to a household latrine (≥15)	%	4.18	Trial data
	Switched from a communal latrine to a household latrine (5-14)	%	3.65	Trial data
	Switched from a communal latrine to a household latrine (≥15)	%	2.95	Trial data
	Switched from a neighbor's latrine to a household latrine (5-14)	%	48.99	Trial data
	Switched from a neighbor's latrine to a household latrine (≥15)	%	20.35	Trial data
	Saved time from the switch (open defecation, round trip)	minutes	9.13	Trial data
	Saved time from the switch (a communal latrines, round trip)	minutes	10.00	Trial data
	Saved time from the switch (a neighbor's latrine, round trip)	minutes	4.50	Trial data
	Number of diarrhea cases avoided per year (5-14)	cases	0.41	Trial data
	Number of diarrhea cases avoided per year (≥15)	cases	0.32	Trial data

The number of diarrhea cases avoided, premature deaths averted, and hours saved are presented in Table 3. We estimate that 20,374, 16,084, and 15,154 cases of diarrhea would be avoided for each age group from under-5 children to the working-age population (aged 15 or above) over 10 years after the CLTS intervention in the intervention villages. Twenty-two premature deaths would be averted over the 10-year horizon. Furthermore, 412,893 hours are projected to be saved from the avoided diarrhea cases, and 2,064,902 hours are expected to be saved by switching from open defecation or utilization of communal or neighbors' latrines to a household latrine.

Table 3. Health and time benefits from the CLTS intervention

	<5	5-14	≥15	SUM
Diarrhea cases avoided	20,374	16,084	15,154	51,612
Premature deaths averted	14	3	5	22
Time saved from taking care of sick people (hours)	162,989	128,673	121,231	412,893
Time saved from the switch to a household latrine (hours)		1,101,556	963,346	2,064,902

Table 4 summarizes benefits and costs, by age group and overall. Avoided premature deaths accounted for 58% of the total benefits, followed by time savings from increased access to household latrines. The absolute value of health benefits was highest for under-5 children. Figure 2 visualizes the distribution of benefits by item and age group (Figure 2a and Figure 2b, respectively). Forty-five percent of economic benefits came from the avoided diarrhea cases and premature deaths of children under-five. In the base case, achieving these benefits assumes that the effects seen at trial endline (10 months after the CLTS triggering) are sustained throughout the 10 years.

The cost of community and local stakeholders' investments in CLTS activities was Int'l $186,690, constituting 42% of total costs. The benefit-cost ratio (BCR) was 3.7 and the net present value was Int'l $1,193,786. If we consider slippage, the BCR was 3.1 and the net present value Int'l $916,500 (Table S3). The BCR was 4.3 and the net present value Int'l$1,453,794 when incorporating population growth (Table S4).

Tables 5-6 present details of the costs of program implementation, management, and the time and material commitment of local people.

Figure 3 and Figure 4 present the results of the one-way sensitivity analyses. The largest changes in benefit-cost analysis outcomes were yielded by the effects on diarrhea of the CLTS intervention and the useful life of an improved latrine. VSL and the discount rate were the next most influential parameters. The changes in response to variation in other parameters in the BCR and NPV were minimal.

Figures 5 and 6 present the results of the Monte Carlo simulations with the cumulative density functions of the BCRs and NPVs of 10,000 draws. The 5th and 95th percentile of NPVs were Int'l $406,017 and Int'l $1,977,960. The 5th percentile of the BCR was 1.9, while the 95th percentile was 5.4.

Table 4. Benefits and costs over 10 years (present value in 2016, Int'l $)

Item			Age group <5	5-14	≥15	Sum	%
Benefits	Avoided diarrhea cases	Treatment costs saved	3,294	1,305	1,230	5,829	13%
		Transportation costs saved	3,386	2,312	2,178	7,876	
		Meal costs saved	903	465	439	1,807	
		Accommodation costs saved	337	97	130	564	
		Caregiver time saved	51,769	20,435	38,506	110,709	
		Health professionals' time saved	63,003	12,477	11,756	87,236	
		Sum	122,692	37,091	54,239	214,021	
	Averted premature deaths	Value of statistical life	611,103	137,839	194,801	943,744	58%
	Time saved from increased accessibility	Switch from open defecation		33,469	118,927	152,396	29%
		Switch from using communal latrines		46,949	91,930	138,878	
		Switch from using neighbors' latrines		94,521	95,124	189,645	
		Sum		174,939	305,981	480,919	
	Grand total		733,795 (45%)	349,869 (21%)	555,021 (34%)	1,638,684 (100%)	100%
Costs	Initial costs						
	Project implementation & management	Recurrent				223,845	54%
		capital				14,580	
		sum				238,425	
	Investment of community and local stakeholders	Recurrent				102,353	42%
		capital				84,337	
		sum				186,690	
	Sum of initial costs					425,115	
	Operation & management	Operation & management				9,892	4%
	Education for the lifespan of a latrine	Education				9,892	
		Sum				19,784	
	Grand total					444,899	100%
Benefit-Cost Ratio (BCR)				**3.7**			
Net Present Value (NPV)				**1,193,786 (49,741 per community; 687 per household)**			

Table 5. Initial costs (program implementation and management, Int'l$)[a]

		Item	Cost
CLTS implementation	Recurrent	CLTS promoter introduction	1,200
		CLTS promoter training	2,160
		Educating mothers	2,160
		Community campaign	1,800
		Information, Education and Communication Materials	9,000
		Best promoter prize	2,670
		CLTS training	5,355
		CLTS implementation	2,651
		Experience sharing	720
		Material incentives	3,840
		Monitoring/follow-up	43,204
		Meeting/workshop	4,800
		Sum	79,560
Project management	Capital	Motorcycle	5,590
		Vehicle	8,990
		Sum	14,580
	Recurrent	Korean staff	78,000
		Management staff salary	24,840
		Translator	3,600
		Stationery	4,520
		Drivers	4,800
		Fuel	12,000
		Office	3,600
		Monitoring and evaluation	8,925
		Report printing	4,000
		Sum	144,285
Sum	Recurrent		223,845
	Capital		14,580
		Grand	238,425

[a]Source of data: Project financial records. All were funded by KOICA

Table 6. Initial costs (community members' and local stakeholders' investments, Int'l$)

	Item	Participants	Number of people	Hours per person	Hourly Income[a]	Cost
Recurrent[b]	CLTS training	District health officials	5	56	4.50	1,260
		Health professionals (health center)	5	56	2.54	711
		Health extension workers	24	56	1.79	2,400
	CLTS promoter training	CLTS promoters	38	32	0.67	817
	CLTS orientation	District health officials	3	8	4.50	108
		CLTS promoters	38	8	0.67	204
	CLTS triggering	District health officials	5	40	4.50	900
		Health extension workers	24	192	2.54	11,704
		CLTS promoters	38	304	0.67	7,740
		Community members	804	8	0.67	4,311
	CLTS follow-up	District health officials	5	256	4.50	5,760
		Health extension workers	24	256	1.79	10,998
		CLTS promoters	38	512	0.67	13,036
		CLTS committee	72	128	0.67	6,175
		Community members	1079	32	0.67	23,127
		Kebele leaders	24	64	0.67	1,029
	Review meeting	District health officials	12	64	4.50	3,456
		Health extension workers	24	64	2.54	3,901
		CLTS promoters	38	64	0.67	1,629
		CLTS committee	72	64	0.67	3,087
	Sum					102,353
Capital[c]	Latrine construction (time)	Community people	872	120	0.67	70,107
	Latrine construction (cement)	Community people	71		27.90	1,968
	Latrine construction (handwashing facility)	Community people	721		17.01	12,263
	Sum					84,337
Grand sum						186,690

[a]in the case of latrine construction (for both cement and handwashing facility belong to capital item), it means unit price per household

[b]Source of data: Project report (monthly, annual and final reports), household interview results

[c]Household interview results

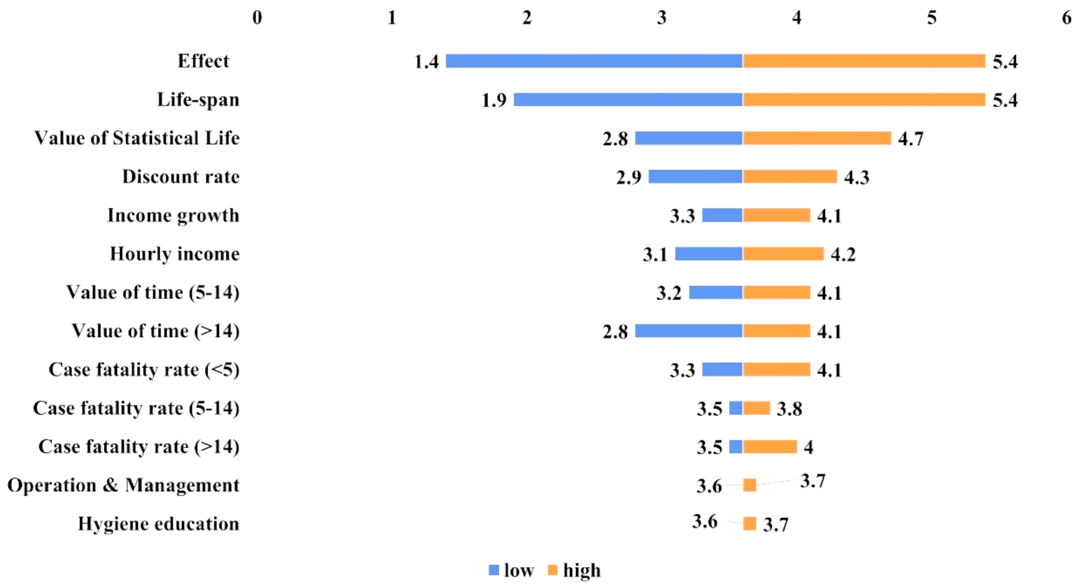

Figure 3. Results of one-way analyses (Benefit Cost Ratio)

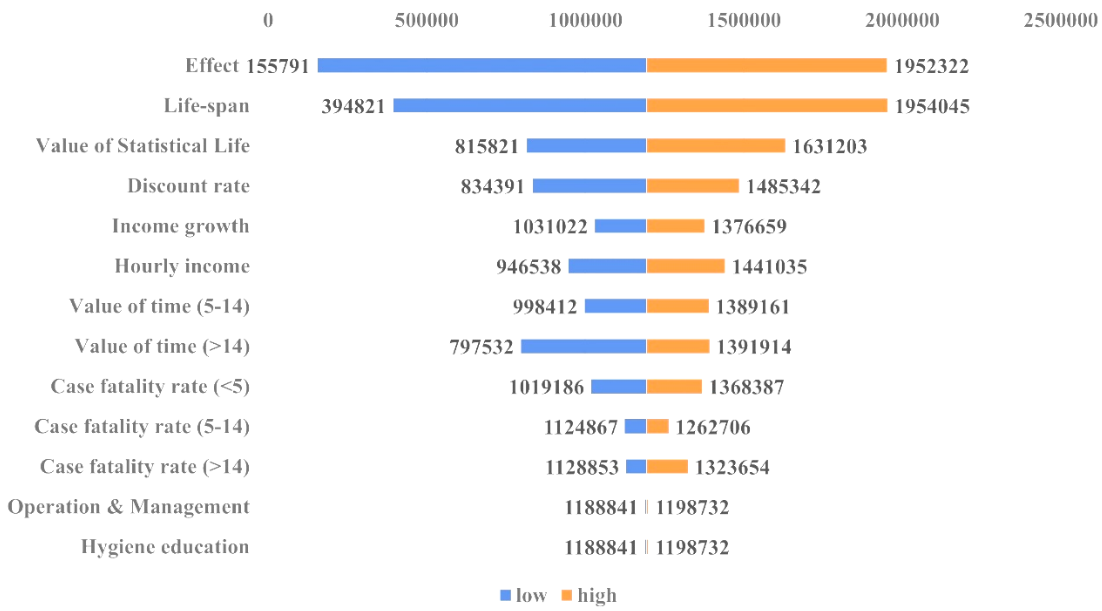

Figure 4. Results of one-way analyses (Net Present Value in 2016, Int'l$)

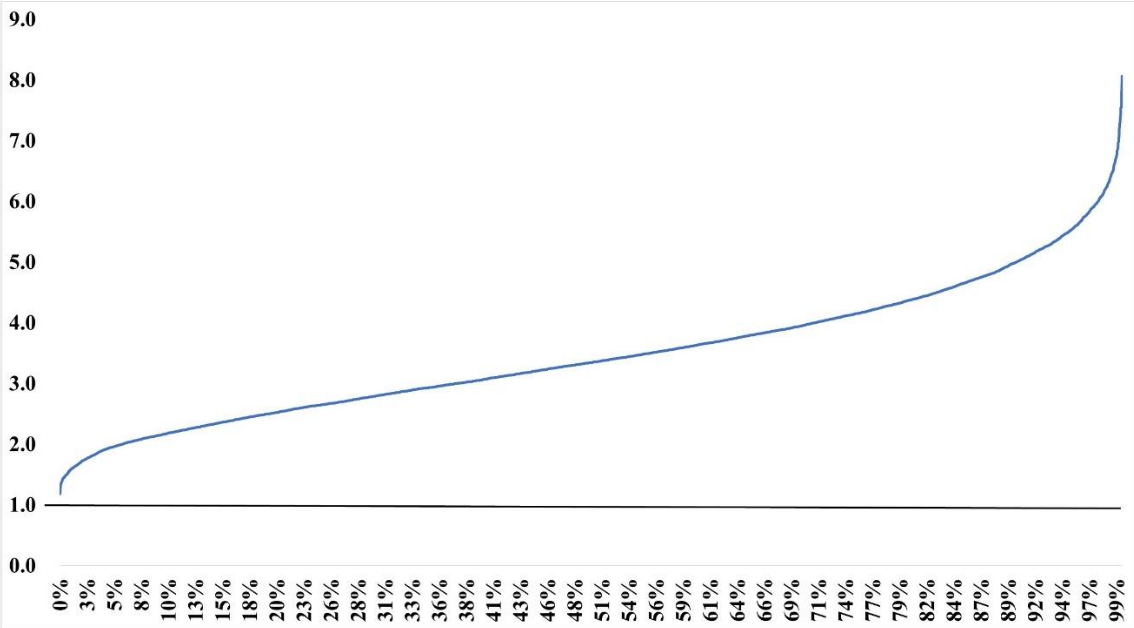

Figure 5. Cumulative probability of the benefit-cost ratio (Monte Carlo analysis, x-axis: cumulative percentage, y-axis: benefit cost ratio)

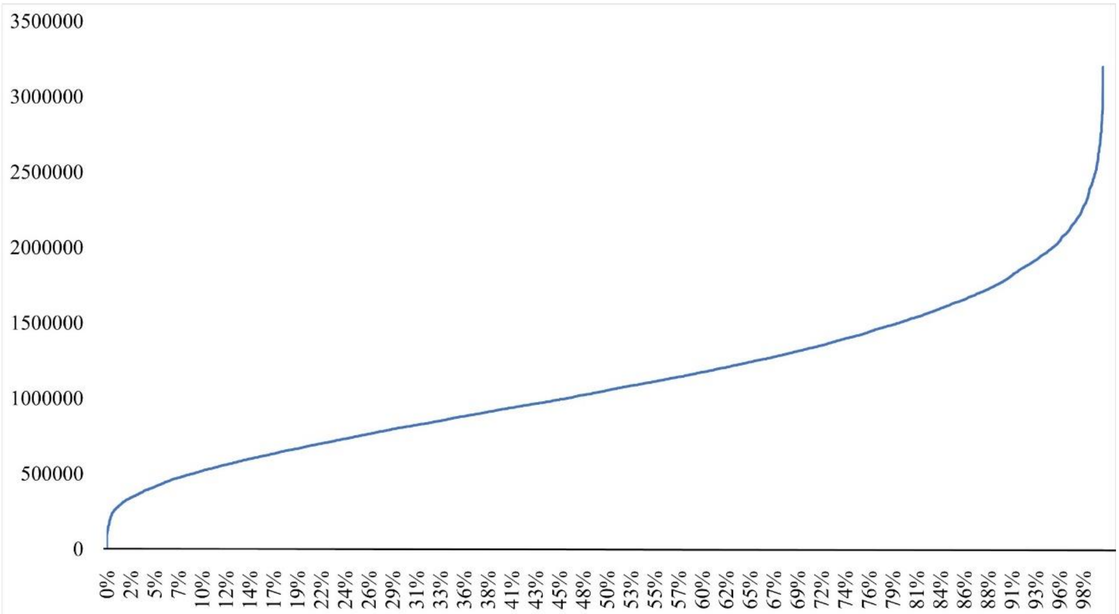

Figure 6. Cumulative probability of net present value (Monte Carlo analysis, x-axis: cumulative percentage, y-axis: net present value, unit: Int'l$)

4. Discussion

This study suggests that a CLTS intervention could yield a favorable return on investment, with a base case BCR of 3.7 and NPV of Int'l $1.2 million over a 10-year time horizon. The probabilistic sensitivity analysis results of a Monte Carlo simulation indicated substantial uncertainty but BCRs consistently greater than one (95% CI 1.9 – 5.4).

Results for benefit-cost metrics in our study are similar to those of many existing hypothetical models and ex-post studies [12,13,17]. These are benefit-cost analyses of global level sanitation improvements or a pilot rural sanitation intervention in India, all of which were not a CLTS intervention [12,13,17]. In our study, we used empirical results of a randomized trial to provide many parameter values, including the effects of the CLTS intervention, baseline conditions, time savings, care-seeking behavior, and the relative contribution of inpatient and outpatient care.

A recent cost-benefit study of a hypothetical CLTS intervention found that CLTS interventions were not as attractive as some previous studies suggested [16]. They argued that the high benefit-cost ratios or net benefits of the majority of existing models of sanitation improvements were mainly derived from not incorporating the costs of time commitment of community members. We accounted for the investments of CLTS facilitators, CLTS promoters, and community members in terms of their time and material commitment, and the benefit-cost ratio and net benefits remain attractive.

It is worth to note that outcomes in our study are almost identical to those in hypothetical analysis for high-uptake villages with external effect by Radin and colleagues [16]. They defined a 35 percentage of coverage increase as high-uptake villages. In our trial, there was 35.0% increase of improved latrine at 10 months after the CLTS triggering (Figure 1) [22]. In addition, partially improved latrine increased from 11.8% at baseline to 34.0% at 10 months after the triggering. Thus, the coverage increase in our trial can be categorized as high-uptake in Radin's study. For external effect, we assessed the effect of a CLTS intervention on diarrhea using an intention-to-treat analysis, regardless of community members' ownership of a latrine or an improved one. This means that we estimated the benefits of the CLTS intervention based on the finding that a reduction in diarrhea cases would occur community-wide in the villages that received the CLTS intervention. This can be interpreted as external effect in Radin's study. Notably, the benefit-cost analysis was 3.7 in our analysis and 3.8 for high-uptake group with external effect in their analysis. The proportion of benefits from time saving is also similar between our trial and their estimation, 29% and 30%, respectively. All in all, the two studies show high consistency in the results.

The effect size of the CLTS intervention and the life of a latrine were established as the two most influential parameters in our estimation. In this study, a substantial share of benefits was attributable to the protective effects of the intervention against diarrhea. Many recent trials, though not all, have suggested that sanitation improvements including CLTS interventions were not effective against diarrhea [39-43]. However, we identified an effect similar to the results of recent systematic reviews on sanitation improvements [44,45]. Achieving a near universal coverage of improved latrines (pit latrines with a slab) based on the definition of Joint Monitoring Programme (JMP) of WHO/UNICEF [2], as opposed to the unimproved latrines typically achieved under CLTS, might have been the key factor underlying the reduction of the longitudinal prevalence of child diarrhea in the intervention villages.

Notably, this study reported that the CLTS intervention yielded net economic benefits, even in the context of low prevalence of open defecation (OD) prior to the intervention. The proportions of households that had a simple pit latrine and safely disposed children's feces were already high. Previously, many studies based on hypothetical models assumed the majority of people to be defecating openly at baseline, leading to a high proportion of benefits originating from time savings. The substantial health benefit identified in the trial informing our study may have been due to the majority of service level transitions being from "unimproved" to "improved", rather than from "OD" to "unimproved" as is often achieved with CLTS [22,46,47]. Furthermore, there was a significant reduction in the fly count around pit-holes in the intervention group compared with the control group [22]. Chavasse and colleagues found that diarrhea was substantially reduced (period prevalence ratio of diarrhea in the intervention group compared with the control group: 0.78, 95% CI 0.64-0.95, p=0.01) after controlling flies [48]. If the CLTS intervention were implemented more intensively, leading to even higher coverage of improved latrines, we might expect greater benefits.

This study has some limitations. For VSL, we extrapolated the values using the VSL income elasticity. The limitation of this method is that changes in income elasticity could lead to a large difference in VSL values [27]. Thus, we included this parameter in our sensitivity analysis, and the results indicate that the CLTS interventions yield high returns on the investment even when assuming the lowest value of VSL.

When cross-checking parameter values, we found that the treatment and transportation costs reported by caregivers were higher than those suggested by government officials in the districts. Although it is plausible that caregivers had to make extra payments not related to official charges or fees, we used the values reported by government officials to make a conservative estimation of the benefits. When using the treatment and transportation costs reported by caregivers, outcomes slightly increased (Table S5). We included all the expenses and salaries for the Korean staff in the cost estimation. The key task of the Korean staff was to manage the project and report monitoring results to the donor, the Korean government. We think that a CLTS intervention with similar intensity could be replicated without support from a foreign project manager. Correspondingly, the costs might be reduced in future interventions. We did not include other possible health benefits such as reductions in diseases other than diarrhea or changes in nutritional status. Nor did we include quality of life benefits related to dignity or safety, in the absence of quantitative means for their valuation. Therefore, we infer the true BCR and NPV would be higher than those we estimated in this study.

5. Conclusions

The outcomes of benefit-cost analyses strongly depend on local conditions regarding key parameters. Our study shows that the benefits of a CLTS intervention in rural Ethiopia exceeded its costs by a reasonable margin in the base case and under plausible scenarios in sensitivity analyses. The context of the rural areas where we conducted the trial has typical features of remote areas of sub-Saharan African countries in terms of low coverage of improved water and sanitation, remoteness of villages, high prevalence of diarrhea, and low socioeconomic status. Therefore, the net benefits identified in this study could be replicated in many similar settings and taken to scale. CLTS interventions have the potential to bring considerable benefits to people in rural areas, if implemented effectively in the right settings. These settings include areas where open defecation practices are rampant, latrine coverage is low, and the prevalence of diarrhea is high at baseline.

Supplementary Materials: Supplementary Materials: The following are available online at http://www.mdpi.com/1660-4601/17/14/5068/s1, Table S1: Parameter distribution and justification, Table S2: Parameter values (base case), Table S3: Benefits and costs reflecting slippage (average annual reduction: 3.5%) (present value in 2016, Int'l $), Table S4: Benefits and costs reflecting the population growth of 2.7% (present value in 2016, Int'l $), Table S5: Benefits and costs reflecting the treatment and transportation costs reported by caregivers (present value in 2016, Int'l $), Text S1: Comparisons of the interventions between the intervention and the control groups, Text S2: CHEERS checklist, Text S3: Lifetime of an improved latrine in this study, Figure S1. Distribution of benefits by item, Figure S2. Distribution of benefits by age group.

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Chapter 7. Discussion and conclusion

General Discussion

The aim of this thesis was to evaluate the health and economic effect of a CLTS intervention implemented in rural Ethiopia. The specifics of the intervention and trial are outlined in the study protocol (Research Paper 1). The three distinct objectives of the DrPH thesis were to 1) evaluate the effect of a CLTS intervention on child diarrhea (Research Paper 2); 2) examine the performance of pit latrines and their herd protective effect (Research Paper 3); and 3) assess the economic efficiency of a CLTS intervention (Research Papers 4). This chapter provides a summary and synthesis of key findings, interpretations and policy implications, discussess strengths and limitations of this study, and offers recommendations.

Main Findings

Objective 1: Evaluate the effects of a CLTS intervention on child diarrhea

The first objective was addressed in Research Papers 1 and 2.

A cluster RCT was conducted to evaluate the effects of a CLTS intervention in the rural area of the SNNPR state in Ethiopia. The CLTS intervention was carried out as part of an integrated water, sanitation and hygiene project funded by the Korea International Cooperation Agency (KOICA). Alongside the CLTS intervention, improvements to the water source were also implemented in 212 communities. However, these water-access interventions were only inititated after the trial was completed. A Korean NGO in collaboration with the Ministry of Health in Ethiopia, implemented this CLTS intervention. The CLTS triggering took place in February and March of 2016, with post-triggering follow-ups conducted until one year after the triggering. A household-based baseline survey was carried out at three months prior to the triggering for entrollment purposes, and follow-up surveys were conducted at 3, 5, 9, and 10 months post-triggering. In addition to the period prevalence of child diarrhea based on parental reports, the incidence and longitudinal prevalence of diarrhea were measured using a diarrhea calendar. This tool allowed caregivers to record daily episodes of diarrhea for their youngest under-five child.

The intervention had a significant effect on the period prevalence 3 months post-triggering but this effect diminished over the remaining follow-up periods. Over the course of 140 days, as recorded in the diarrhea calendar, both incidence and longitudinal prevalence saw a significant decrease in the intervention group compared to the control group. At the outset, the coverage of any type of latrine was high in both the intervention and control communities. The intervention, therefore, encouraged the adoption of an improved household latrine during its implementation. In this study, an improved latrine was characterized as having a pit deeper than 2 meters, a pit hole cover, slab, wall, door, roof, and a handwashing facility equipped with soap. There was a significant increase in the coverage of study-improved latrines in the intervention communities compared to the control communities (35.0% vs 2.8%), but it fell short of the 70% target set for the intervention. An assessment of latrine use, based on four proxy indicators, found no difference between the intervention and control groups.

In our trial, we were unable to detect a significant effect, particularly in terms of period prevalence. There may be several reasons for this when considering the intermediate outcomes between the intervention and control groups. Firstly, the latrine coverage for improved latrines in the study was limited to 35%, with only a 32% difference between the two groups. Secondly, transmission pathways may have only partially been interrupted. The presence of feces both inside and outside of the compound did not show a significant difference between the two arms, although some difference was observed at various points throughout the study. We were unable to detect a substantial difference in the use of any type of latrine between the two groups. The coverage of improved latrines did not reach the 70% target that we had set when developing the study protocol. Total sanitation was not achieved in the intervention. These factors likely contributed to the lack of a significant effect of the intervention on reducing the period prevalence of child diarrhea. The status of soil infection and water contamination was not measured.

The trial provided evidence that the CLTS intervention in rural areas of Ethiopia reduced the incidence and the longitudinal prevalence of child diarrhea. There was no clear evidence of effect on 7-day period prevalence over longer follow-up duration beyond three months and duration of diarrhea. In previous trials, diarrhea measurements were done only once or at a few time points (Clasen et al, 2014; Humphrey et al., 2019; Null et al., 2018; Pickering et al., 2015). A typical measurement point in previous trials was 12 months after the intervention. We assessed diarrhea cases throughout the rainy (June-August) and dry seasons. Diarrheal illness was measured at 140 time points from 3 months to 10 months after the CLTS triggering. If we had assessed diarrhea prevalence only at 10 months after the triggering, we would not have been able to detect the effects of the CLTS intervention in this study. Longitudinal prevalence of diarrhea decreased over time both in the intervention and the control villages. I infer that seasonal variation and the increased coverage of partially improved latrines even in the control group could have contributed to this change. I noticed that the reduction in diarrhea in the intervention group was more substantial during the earlier period of the CLTS intervention in terms of longitudinal prevalence and incidence. This is consistent with the fact that the coverage of improved and partially improved latrines increased more substantially in the early period of the intervention, as shown by 26.6% and 42.4% increases in improved and at least partially improved latrine coverage for the first 3 months, in comparison to 8.4% and 14.5% increases during the next 7-month period.

This study reported that a number of indicators had improved more at the 10-month follow-up than at earlier times after the triggering, and it may be possible that the effect on the incidence and the longitudinal prevalence of child diarrhea could have been more pronounced with a longer follow-up period if post-triggering activities had continued. This possibility is especially likely since the households with partially improved latrines were in the process of constructing improved household latrines. However, this does not guarantee that the outcomes can be sustained after post-triggering or post-ODF activities stop. Previous studies suggested that the effects of an intervention may wane over time, particularly beyond 1 year after an intervention (Null et al., 2018). I suggest institutionalizing a system for sanitation improvement so that post-triggering or post-ODF activities can be routinely carried out by government officials, community health workers, and the like (Orgill-Meyer et al., 2019).

I thus infer that the reduction in longitudinal child diarrhea could be attributed to the expanded coverage of a study-improved latrine. This deduction is based on the significant difference in certain intermediate outcomes related to the transmission pathway of faecal-oral contamination between the two groups. For example, the number of flies around the pit-hole and the presence of faeces on the latrine floor were notably reduced in the intervention group compared to the control communities.

Objective 2: Assess the performance of pit latrines and herd protective effects of improved latrines

The second objective was addressed in Research Paper 3.

As described in other parts of the thesis, latrine coverage was already high in both arms prior to the initiation of the intervention. The latrines we examined before the trial's design were no better than areas designated for "fixed point open defecation" (Kar, 2008). Consequently, I emphasized the significance of an improved latrine that properly contain faeces, as this can contribute to health improvement. I formulated an operational definition for an improved latrine, drawing upon a review of various types of pit latrines recommended by many numerous development organizations.

The performance of pit latrines in reducing child diarrhea showed no difference between improved and unimproved latrines, according to the JMP definition of improved latrines. However, I found that the improved latrines (study-improved), as operationally defined in this study, demonstrated superior performance in reducing child diarrhea compared to both unimproved latrines and those classified as improved latrines under the JMP definition.

A herd-protective effect of improved latrines was observed when latrine coverage reached 70 %, as per JMP improved latrine standards. The odds of children experiencing diarrhea in households with either “non-improved latrines” or “no latrine” was significantly lower in high coverage communities compared to those in low coverage communities with the same latrine conditions.

JMP-improved latrines had no direct effect on diarrhoea in this study but high coverage with JMP-improved latrines appeared to produce a herd effect of sanitation after some months. Based on this, one could argue that JMP-improved latrines still have a value even if this study overall suggests higher quality latrines to have a larger impact at a higher cost. The above highlights the quality/impact trade off that may have to be made when considering latrine options. However, high quality latrines may be preferable on the grounds of equality.

Objective 3: Estimate the costs and benefits of the CLTS intervention

The third objective was addressed in Research Papers 4.

In this study, I used empirical results of a randomized trial to provide parameter values, including the effects of the CLTS intervention, baseline conditions, time savings, care-seeking behaviour, and the relative contribution of inpatient and outpatient care. A recent cost–benefit study of a hypothetical CLTS intervention found that CLTS interventions were not as attractive as some previous studies suggested (Radin et al., 2020). The authors argued that the high benefit–cost ratios or net benefits of the majority of existing models were mainly a result of not incorporating the costs of the time commitment of community members. I accounted for the investments of CLTS facilitators, CLTS promoters, and community members in terms of their time and material commitment, and the benefit–cost ratio and net benefits remain attractive in this setting. I estimated the benefits of the CLTS intervention based on the finding that a reduction in diarrhoea cases would occur community-wide in the villages that received the CLTS intervention. This is analogous to the externality in Radin's study (2020).

An economic evaluation of the CLTS intervention suggested that the benefits of the CLTS surpassed the costs. It was found that every dollar of investment yielded 3.7 dollars for society. The labor of these community members was identified as the largest cost, while the great benefit was suggested to be the reduction of diarrhea. When broken down by age group, children under-five were found to reap the most benefits.

However, I could not include other benefits than diarrhoea in the absence of empirical data in our trial. Therefore, I infer that the true BCR and NPV would be higher than those I estimated in this study if measured comprehensively, and this possibility warrants future study.

Synthesis of Findings and Reflections on the thesis

I designed a cluster RCT to investigate the effects of a CLTS intervention on child diarrhea. In this trial, we encouraged the use of low-cost latrines that are both accessible and affordable for households in rural Ethiopia, while also emphasizing the importance of latrine quality. This approach differs from the conventional CLTS method, which does not suggest a specific latrine design. Instead, this study highlighted the minimum requirements for latrines to be constructed by households.

What was known and not known prior to this trial?

The most recent meta-analysis of cluster RCTs examining various sanitation interventions indicated a risk ratio of 0.87 (95% CI, 0.77–0.97) for child diarrhea in the intervention group compared to the control group. However, only two RCTs reported a significant decrease in child diarrhea among the 12 community-based interventions studied.

Public health researchers and specialists have proposed a variety of explanations for these unexpected results (Cameron et al., 2013; Clasen et al., 2014; Patil et al., 2014; Crocker et al., 2016a/b; Hammer and Spears, 2016; Briceño et al., 2017). Numerous original and review papers have attributed the minimal or non-existent impact on health outcomes to the low coverage and/or usage of latrines (e.g., Cumming & Curtis, 2018; Cumming et al., 2019). The average increase in latrine coverage was 18 percentage points for any type of latrine and 13 percentage points for JMP-improved latrines (Radin et al., 2020). However, none of the trials achieved near-universal latrine coverage. Only in the trials conducted by Luby et al. (2018), Humphrey et al. (2019), and Null et al. (2018) did coverage exceed 70%. Regarding usage, only Humphrey's trial (2019) reported a rate of more than 70%, while all other trials either failed to reach this level or did not report the proportion of latrine use. In the study by Humphrey et al. (2019), the intervention was based at the household level, making it unclear whether the latrine uptake could accurately represent community coverage.

In addition, few RCTs have thoroughly explored the comprehensive links within the results chain, from the intervention to output, intermediate outcomes, and diarrhea. None of the RCTs have examined the effect of sanitation interventions on all the transmission pathways as indicated by the intermediate outcome indicators. Some trials, such as those by Dickinson et al. (2015); Hammer & Spears (2016); Briceno et al. (2017) did not report any indicators related to latrine quality. While some trials did report on these indicators, they did not cover all the components listed in Table 2 in chapter 2. For instance, Luby et al. (2018) reported on the presence of faeces on the latrine floor, Sinharoy et al. (2017) on faeces in the yard and handwashing facilities, Null et al. (2017) on handwashing facilities, Quarttrochi et al. (2021) reported on fly numbers, Clasen et al. (2014) on fly numbers and handwashing facilities, and Pickering et al (2015) on fly numbers, handwashing facilities, faeces on the latrine floor, and faeces in the yard. Cameron et al (2013) reported on handwashing facilities, and Patil et al. (2014) faeces in the yard. Luby et al. (2018) observed a significnat reduction in faeces on the latrine floor, while and Pickering et al. (2015) found mixed performance, with good results in terms of the absence of flies, absence of faeces in the yard, and presence of handwashing facilities, but not in terms of faeces on the latrine floor. All other trials that reported on latrine quality found no difference in latrine performance between the two arms. The quality of latrines was suggested as another potential reason for the lack of effect on diarrheal reduction by Clasen et al. (2014) and Briceno et al. (2017). However, this observation does not appear to have been thoroughly incorporated into subsequent trials or reviews.

Recent reviews have not systematically examined the effects of improved sanitation on the interruption of faecal-oral transmission, specifically in relation to latrine quality or type. In certain interventions, even basic pit latrines were utilized (Cameron et al., 2013). There were few trials that thoroughly evaluated whether the latrines used in their interventions effectively isolated faeces from the environment, or whether the latrines successfully prevented individuals from coming into contact with faeces.

Some researchers have identified other sources of pathogens or contamination pathways as potential reasons for the small to moderate effects observed, including animal faeces, which cannot be addressed by latrines alone (Clasen et al., 2014; Briceño et al., 2017; Cumming and Curtis, 2018; Humphrey et al., 2019). Other possible explanations include excessively high latrine coverage or an exceptionally low prevalence of diarrhea at baseline (Cameron et al., 2013; Crocker et al., 2016a/b; Hammer and Spears, 2016; Coffey and Spears, 2018; Cumming and Curtis, 2018; Null et al., 2018). The former suggests an insufficient target population for sanitation interventions, while the latter indicates a lack of study power, especially if the actual prevalence in study areas was significantly lower than the researchers' initial estimates at the time of trial design. In light of these findings, many researchers have called for additional studies to investigate effects of sanitation interventions and sanitaion externalities, as well as the potential benefits they could bring to a community.

What did the thesis do to close the knowledge gap?

Many of the existing trials failed to investigate various aspects of the results chain. Interpretations and explanations regarding the presence or absence of an effect were made without considering the effect of their interventions on comprehensive intermediate outcomes within the results chain of their trials.

In this thesis, I tried to close this research gap as follows.

At the intermediate level, concerning latrine quality, I evaluated whether the intervention had decreased the likelihood of fecal-oral transmission. This was done by measuring indicators of fecal-oral contamination, such as: the presence and quantity of faeces on the latrine floor; the presence and quantity of faeces both within and outside the household compound; the presence and quantity of flies around the latrines' pit hole; and the presence of hand washing facilities as a component of the latrine. At another intermediate level, focusing on access, use, and collective behavior, I assessed latrine coverage, usage, as well as the disposal of child faeces.

According to a recent review on the costs and benefits of sanitation by Radin et al. (2020), most cost-benefit alalyses were either theoretical estimations or based on observational studies. No cost-benefit analysis was derived from an RCT. Existing RCTs did not report many of the parameters necessary for cost-benefit or cost-effectiveness analysis. Consequently, the majority of existing studies relied on systematic and/or meta-analysis results to determine the effects of interventions on health outcomes (Radin et al., 2020).

Most CBA studies did not account for the actual change in coverage or use of sanitation observed in their interventions. Instead, they relied on benefit-transfer methods for parameter valuations, rather than utilizing empirical data from each intervention. Futhermore, sanitation externalities were not considered. All these factors could have led to imprecise estimations of benefits and costs, as many parameter values are context-specific. For example, the time saved by transitioning from open defecation to latrine use, or the time spent constructing latrines or participating in interventions, may vary depending on the context or program settings. In a recent review of RCT trials, Radin (Radin et al., 2020) identified more than 50 parameters necessary for the cost-benefit analysis of sanitation interventions, some of which were incorporated into the cost-benefit analysis in this thesis (Cha et al., 2020).

What are the key interpretations or syntheses of the overall results?

To start, the findings related to primary and intermediate outcomes are described below.

First, the primary outcome was child diarrhea. The trial yielded mixed results in this area. A modest effect was observed on longitudinal prevalence of child diarrhea due to a CLTS intervention. However, the effect found on period prevalence 3 months post-CLTS triggering was not sustained in subsequent periods.

For the intermediate outcomes, the results were as follows:

1. There was no difference in latrine use between the intervention and control groups.

2. There was a modest difference in study-improved latrines between the two comparison groups. The intervention group demonstrated a 32.3% higher coverage of study-improved latrines than the control group.

3. The CLTS intervention had an effect on interrupting some of potential faecal-oral transmission pathways, but not all, as indicated by the following proxy indicators:

   ① The risk of households posessing latrines where faeces were observed on the floor, and the number of flies observed around the pit-hole, was lower in the intervention group than in the control group.

   ② The proportion of households that appropriately disposed of child faeces did not differ between the two groups.

   ③ At the same time, we found that the risks associated with 1) the presence of faeces on the latrine floor, and 2) an increased number of flies around the pit hole, were higher in unimproved latrines compared to those that were operationally defined as improved in this study.

   ④ By definition, a study-improved latrine always includes a handwashing facility with soap and water. The proportion of households with installed latrines with appropriate handwashing facilities was higher in the intervention than in the control group.

4. Thus, the lower risks of having latrines where faeces were observed on the latrine floor and also flies were observed around the pit hole in the intervention group than the control group might have been attributable to the larger proportion of individuals with a study-improved latrine in the intervention group than that in the control group.

Based on these findings, I conclude that the reduction in the longitudinal prevalence of child diarrhea in the intervention communities can be attributed to the effect of a CLTS intervention, which lead to an increase in the coverage of higher quality latrines.

Policy implications of the thesis

1. **Reconsidering the definition of an improved latrine**

   The definition of an "improved latrine" should be revisited at least in the research areas, with a focus on gathering more substantial evidence through rigorous investigation. This is to ascertain whether it can effectively contain faeces to prevent fecal contamination. The redefinition should place greater emphasis on the latrine's performance or functionality in interrupting transmission. Consequently, some latrines currently classified as "improved latrines" might need to be reclassified as "unimproved".

2. **Quality of latrines**

   In numerous sanitation interventions, particularly those involving CLTS, the importance of latrine quality appears to have been neglected. Up until now, the emphasis on latrine quality or design has not been adequately addressed for the following reasons:

   ① One of the key principles in the conventional CLTS approach is not to make suggestions regarding the latrine design. Dr. Kamar Kar, the founder of CLTS, argued that placing emphasis on latrine design could lead to issues of inequality. He suggested that the most vulnerable individuals within a commonnity could become further marginalized due to their difficulty in accessing higher quality latrines (Kamar Kar, 2019). His concern is understandable, as superior latrine facilities might incur costs that these vulnerable individuals are unable to afford. However, if community members are unable to reap the benefits of a latrine, would they be motivated to continue their climb up the sanitation ladder? Instead, one could deduce that if they experience no advantages from using a latrine, they might revert to their previous practices of open defecation (Tyndale-Biscoe P, 2013).

② Patil et al. (2014) argued that sanitation remains beneficial, even if it does not have a direct effect on health, due to its other social benefits, which might imply that the quality of the latrine is of lesser importance. Ross et al (2022) reported that a sanitation intervention increased quality of life in low-income setting. This claim warrants further empirical research in more various settings to confirm whether the proposed social benefits extend to low quality latrines deemed sufficient in many CLTS interventions.

We need to find better ways to roll out sanitation interventions that are able to deliver high quality toilets, which interventions focussing on behaviour change such as CLTS seem unable to do.

Humphrey et al. (2019) advocated new and innovative interventions “that are less dependent on behaviour change and more efficacious in reducing faecal exposure—a paradigm shift away from how rural WASH programmes are delivered”. I would also propose that we need a rethinking of current sanitatation interventions, which emphasize behavior change, and instead seek an appropriate approach towards achieving universal sanitation coverage, given its low compliance rate.

Strengths and limitations of the thesis

This study aimed to minimize measurement error and bias. Unblinded randomised trials relying on subjective outcomes such as self-reported diarrhoea are prone to bias. To circumvent recall bias, I employed a diary method to record episodes of child diarrhea, supplementing the 7-day period prevalence reported by caregivers. This diary method also addressed the issue of insufficient study power, as it allowed for the tracking daily episodes of child diarrhea over a span of 140 days. By utilizing a calendar, I was able to asssess both the incidence and longitudinal prevalence of diarrhea. This approach facilitated a more accurate count of diarrhea episodes and their duration. However, there remains a risk of bias in that study participants in the intervention arm report diarrhoea episodes differently from those in the control arm, for example due to factors such as social desirability. Where possible, I endeavored to measure key indicators, particularly those susceptible to measurement error or bias such as latrine structure, latrine use, and other significant intermediate outcome indicators, in a more objective manner. The number of flies was counted using a glue trap. The presence of faeces on floor on the floor, inside or outside the household compound was directly observed. Latrine use was monitored using proxy indicators in addition to caregivers' reports. The latrine structure was photographed and cross-verified by supervisors. Some studies have evaluated the effect of sanitation interventions on nutritional outcomes, which can be assessed objectively. However, nutritional outcomes were not examined in this study. While this was outside the purview of our trial, the thesis's exclusive focus on caregivers' self-reported diarrhea does represent a limitation.

In a randomised trial, confounding is minimised by the random allocation process. However, some analyses in this study, namely the exploration of herd effects did not rely on randomisation and were equivalent to conventional observational studies. Hence, confounding may play a role in that households without a latrine in high coverage villages may differ from their counterparts in low coverage villages in aspects other than latrine ownership. Compliance remained a significant limitation in this trial. Initially, the plan was to assess the effect of study-improved latrines, based on the expectation that we would achieve sufficient coverage. However, this goal was not achieved. As a result, the study was limited to evaluating a sanitation intervention, rather than improved sanitation per se. The coverage of study-improved latrines fell significantly short of the 70% target set prior to the trial. During the final round of the survey, we observed that some households were still in the process of constructing latrines. Unfortunately, we were unable to revisit the target areas to measure progress.

When designing the trial, a priori information on the prevalence of child diarrhea was utilized to estimate an adequate sample size. However, it was later discovered that this prevalence was higher than the actual one, particularly in the later stages of the project within the target area. This discrepancy resulted in a reduction of the study power.

The herd protection effect was evaluated using the JMP definition, which accounted for 70% coverage, rather than the operational definition established in this study due to the low coverage of a study-improved latrine. This led to some interpretive confusion, as I was able to measure the direct effect of a study-improved latrine as defined in this study, but I was not able to investigate the herd protective effect of such a latrine. Instead, the herd protective effect of a JMP-improved latrine was examined.

The sanitation intervention was relatively small-scale, which facilitated a more intensive implementation. For example, it was possible to conducte monthly monitoring at each community to assess the progress of latrine construction and record diarrhea incidents. Health extension workers and project team members carried out monthly monitoring and supervision in each community. Therefore, it may not be guaranteed that the intervention can be scaled up with the same intensity.

Like many other studies, this trial did not assess the long-term effects. Therefore, caution should be exercised, when interpreting the non-significant difference in diarrhea at later stages post-triggering. The observed decline in diarrhea over time in the control communities does not necessarily indicate a waning effect, but this remains a possibility. Strong effects in the early stages of an intervention should be seen in the light of long-term secular trends in the study population that make comparison across study arms increasingly difficult the more time elapses.

A relative reduction of diarrhea cases has been detected throughout the 140-day observation period. Specifically, 481 days of diarrhea out of 57,260 child-days were observed in the intervention group and 773 days of diarrhea out of 60,620 child-days in the control group (a 35% lower number of days observed in the intervention compared to the control group). In the first 62 days of the observation period (starting from June 3), the number of diarrhea days/child-days was 334/25358 and 551/26846 in the intervention and control villages, respectively (a 36% lower number in the intervention compared to the control group). In the next 78 days of the observation period in November 2016 – January 2017, there was 147/31902 and 222/33774 diarrhea days/child-days in the intervention and control villages, respectively (a 30% lower number in the intervention compared to the control group). All of these 140 days of observation were made 3 months after the intervention. The results indicate that a reduction in diarrhea cases was observed throughout the entire observation period even beyond the 3 months after the intervention.

There was a decrease in diarrheal cases throughout the entire intervention period, but the period prevalence decreased rapidly in both the intervention and control groups during the months of November to January. The decrease of diarrhoea might have been due to seasonal changes or secular trends, and limited the power of this study to detect a significant effect in the later part of the follow-up period.

In this study, total sanitation was not assessed. Ideally, we would have needed to examine fecal matter throughout the entire community to determine if it had achieved a level of total sanitation. However, the scope of this trial was limited to the examination of faecal matter within the confines of the household compound and within a 10-foot radius outside of it.

This study does not seek to identify which components of CLTS lead to behavior change, nor does it examine the workings of CLTS. The investigation of the behavior change mechanism was outside the scope of both the trial and the thesis. This could be viewed as a limitation of the thesis from the standpoint of a behavior change advocate, as this study may not contribute new insights to the existing body of evidence in this regard.

Finally, this study was unable to evaluate social benefits, including aspects such as privacy, dignity, privacy, convenience, and safety.

Recommendations for future research or sanitation interventions

Current studies on sanitation interventions have mostly tested “real world” intervention models, in what can be described as effectiveness studies.

Many public health specialists were puzzled by the disappointing results of such trials. My review of the sanitation trials, suggests that the disappointing effects of sanitation interventions in the majority of trials could have been partially due to poor performance at intermediate outcome levels. These includes: 1) the inability of latrines to contain faeces appropriately; 2) low access and usage of latrines; 3) failure to achieve total sanitation.

With this in mind, I propose that we may need to conduct more studies measuring the efficacy of improved sanitation or high-quality latrines under well controlled conditions to truly understand the genuine effect. We may need to make more radical change by moving away from behavior-focused interventions and instead focusing on efficacy studies rather than studying effects. This approach also called for increased support from public sectors. As part of the experiment, universal coverage of improved latrines could be implemented in the study villages. If the trial is solely focused on assessing the efficacy of latrines in reducing diarrhea, latrines could be intentionally distributed to all households in the study areas. This would help us measure the true effect of latrines on child diarrhea, and address some of the limitations seen in previous trials with low compliance.

As stated earlier, Patil et al. (2014) posited that despite the questionable effects of sanitation interventions, they remain valuable due to the social benefits they provide beyond health effect, such as dignity, privacy, time savings and safety. However, it needs to be investigated whether low quality sanitation can offer social benefits in the absence of health effects. The quality of latrines may also be linked to dignatity, comfort, convenience, safety, privacy and numerous other social benefits (Ross et al., 2022), clearly warranting further research.

While this study did suggest the presence of a herd-protective effect from sanitation interventions, it does have several limitations. The model was still unable to explain a significant proportion of the variance of diarrhea at the community level. Further empirical studies are needed to explore herd-protective effects, perhaps also exploring what quality of latrines are needed to achieve herd effects.

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Supplementary materials

Supplementary materials for the Chapter 4

Text S1. Details of the community-led total sanitation intervention in the Gurage zone, Ethiopia

Community-led total sanitation promoters *(CLTS promoters)*

Selection criteria for CLTS promoters

① Eligibility: CLTS promoters should be residents of the community.

② CLTS promoters who met the following criteria were recommended by community leaders or health extension workers (HEWs):

Criterion 1: having attained a basic education level

Criterion 2: being good at communication

Criterion 3: having previous experience as a volunteer

① Nominated members took a written test and were interviewed by district health officials and project coordinators.

Demographic profiles of CLTS promoters

① Male: 79% (27 of 34 promoters); Mean age: 37 years

② Mean years of education: 8 years; Occupation: farmer (100%)

Core tasks of CLTS promoters

① Meeting arrangements and other preparations during pre-triggering

② Active participation as 'an environment setter' during the CLTS triggering process

③ Post-triggering arrangement and follow-up

④ Participation in the training for capacity-building

⑤ Follow-up on the construction of improved individual household latrines in respective *gotts* (recommended to make a weekly visit to every household: giving technical advice for construction, visiting households for sanitation promotion, and sensitizing conversations in the community)

⑥ Participation in monthly review meetings

⑦ Monitoring of latrine improvement progress (see Appendix for the sanitation survey form)

Benefits for CLTS promoters

① A per diem for participation was provided at every training and regular review meeting.

② They were given other training opportunities by the district health office.

③ Clothes and shoes for field operations were provided.

Training for CLTS promoters

① All CLTS promoters were provided with 4 days of training on the topics of improved latrine construction, basics of sanitation and hygiene, and communication skills.

Supervision for CLTS promoters

① Facilitative supervision was monthly provided by the monitoring team, made up of the district health officials, health professionals from health centers, and the HEWs from health posts

② The HEW at each health post of a *gott* supervised CLTS promoters (the HEW to CLTS promoter ratio was 1:1 or 1:2).

③ The monitoring team occasionally did spot checks on CLTS promoters' practices such as home visits during post-triggering.

CLTS facilitators

① HEWs from health posts, health professionals from health centers, and district health officials were selected as health facilitators (25 HEWs; 7 health professionals from health centers; and 3 district health officials).

Training for CLTS facilitators

① All CLTS facilitators were provided with 5 days of training, including 2 days of field-based practice (trainer: Dr. Dawit Belew Bizuneh: a co-founder of CLTSH in Ethiopia).

② Pre- and post-test results of CLTS facilitators' training: (pre-test score of pass [i.e., 70 or more): 2 of 34; post-test: 22 of 34, see Appendix for the questions of the test)

③ CLTS facilitators with a poor score on the post-training test were given additional training.

CLTS triggering

① CLTS triggering was conducted from February 11 to March 2, 2016 in the Enemore Ena district and from March 8 to 18, 2016 in the Cheha district.

Diarrhea calendar

② The diarrhea calendar was distributed from May 30 through June 10, 2016.

Table S1. Differences between those who were followed up and those lost to follow-up

	intervention			control		
	followed-up	loss	p-value	followed-up	loss	p-value
sex of child (female)	49.80%	54.50%	0.57	50.50%	48.00%	0.84
age of child (months)	24.2 (16.5)	26.5 (15.4)	0.32	24.2 (15.3)	22.1 (16.4)	0.51
education of caregivers (grade 1-4, or less)	77.80%	83.00%	0.35	81.30%	78.30%	0.67
occupation of the head (farmer)	75.90%	79.20%	0.62	84.00%	91.30%	0.91
religion of the head	55.20%	58.50%	0.87	65.80%	65.20%	0.96
type of house (thatched roof)	75.30%	71.70%	0.9	79.90%	82.60%	0.93
member of a household	5.7(1.6)	5.3(1.4)	0.15	5.9(1.6)	5.6(1.7)	0.35
number of U5C in a household	1.7(0.7)	1.6(0.7)	0.35	1.6(0.7)	1.7(0.6)	0.43
monthly income (ETB: Ethiopian Birr)	838.3 (650.6)	767.2 (573.0)	0.45	940.9 (755.4)	820.1 (339.1)	0.45

Table S2. Effects of the CLTS intervention on the incidence and longitudinal prevalence of diarrhea (based on calendar records)

	June 3 – August 3, 2016				November 7, 2016 – January 23, 2017			
	Int	Cont	95% CI	p-value	Int	Cont	95% CI	p-value
Total days of diarrhea	334	551			147	222		
Total episodes	138	220			64	78		
Incidence ratio*	0.58		0.38-0.88	0.01	0.88		0.49-1.58	0.67
Incidence ratio†	0.58		0.37-0.92	0.02	0.90		0.50-1.62	0.73
Longitudinal prevalence (*100 days)								
Longitudinal prevalence ratio[a]	0.62		0.44-0.89	0.01	0.87		0.54-1.40	0.57
Longitudinal prevalence ratio[b]	0.61		0.42-0.90	0.01	0.88		0.56-1.39	0.58

[a]Adjusted for clustering effect and stratification (*kebele*).
[b]Adjusted for clustering effect and stratification (*kebele*), household head's religion, income, caregiver's age and education level, child's age and sex, and type of water source

Table S3. Effects of the CLTS intervention on the incidence and longitudinal prevalence of diarrhea (based on calendar records)

	Intervention	Control	95% CI	p-value
Total days of diarrhea	481	773		
Total episodes	202	298		
Total children	409	433		
Person-days	49571	52467		
Incidence (*100 days)	0.4	0.5		
Incidence ratio[a]	0.66		0.45-0.97	0.03
Incidence ratio[b]	0.67		0.46-0.98	0.04
Longitudinal prevalence (*100 days)	1.0	1.5		
Longitudinal prevalence ratio[a]	0.70		0.52-0.95	0.02
Longitudinal prevalence ratio[b]	0.70		0.51-0.96	0.03

[a]Adjusted for clustering effect and stratification (*kebele*).
[b]Adjusted for clustering effect and stratification (*kebele*), baseline value of household head's religion, income, caregiver's age and education level, hand-washing behavior, child feces disposal, latrine use; child's age and sex, type of water source and type of latrine.

Table S4. Effects of the CLTS intervention on diarrhea duration (based on calendars)

	Diarrhea episodes with an interval of 2 or more days ‡	
	Intervention	Control
Total episodes	202	298
Total children	409	433
Duration of diarrhea		
1 day	90 (45%)	124 (41%)
2 days	56 (28%)	91 (31%)
3 days	32 (16%)	36 (12%)
4 days	13 (6%)	18 (6%)
More than 4 days	11 (5%)	29 (10%)
Mean duration (days)	2.4	2.6
Mean difference (days)[a]	-0.2	
95% CI	-0.8, 0.4	
p-value	0.48	
Mean difference (days)[b]	-0.1	
95% CI	-0.7, 0.5	
p-value	0.73	

[a]Adjusted for clustering effect and stratification (*kebele*)

[b]Adjusted for clustering effect and stratification (*kebele*), baseline value of household head's religion, income, caregiver's age and education level, hand-washing behavior, child feces disposal, latrine use; child's age and sex, type of water source and type of latrine.

Table S5. Effects of the CLTS intervention on the 7-day period prevalence

	Period prevalence							
	CLTS	Control	Relative Risk[a]	95% CI	p	Relative Risk[b]	95% CI	p
Overall			0.83	0.60-1.15	0.26	0.76	0.54-1.07	0.12
3 months	11.8% (51/433)	17.2% (72/419)	0.66	0.45-0.98	0.04	0.60	0.39-0.93	0.02
5 months	17.3% (68/394)	17.5% (72/412)	0.98	0.68-1.39	0.89	0.90	0.62-1.30	0.57
9 months	10.5% (44/418)	11.8% (53/451)	0.87	0.52-1.48	0.62	0.97	0.58-1.64	0.92
10 months	7.7% (34/439)	9.9% (42/426)	0.75	0.35-1.60	0.45	0.60	0.26-1.40	0.24

[a]Adjusted for clustering effect, and stratification (*kebele*).
[b]Adjusted for clustering effect, stratification (*kebele*), baseline value of diarrhea, household head's religion, income, caregiver's age and education level, hand-washing behavior, child feces disposal, latrine use; child's age and sex, type of water source and type of latrine.

Table S6. Secondary and intermediate outcomes at 3, 5 and 9 months

Survey period	3 months					5 months				
	Intervention	Control	Risk Difference /Rate Ratio	95% CI	p	Intervention	Control	Risk Difference /Rate Ratio	95% CI	p
Outcomes	433	419				394	412			
Having a household latrine All types	421 (97.2%)	374 (89.3%)	8.0%	2.7%,13.3%	0.003	374 (94.9%)	370 (89.8%)	5.1%	1.7%, 8.5%	0.003
Improved latrine*	115 (26.6%)	6 (1.4%)	25.1%	15.4%,34.9%	<0.001					
Partially improved latrine or better†	236 (54.5%)	56 (13.4%)	41.1%	31.3%,51.0%	<0.001	203 (51.5%)	144 (35.0%)	16.6%	10.3%,23.0%	<0.001
Hand washing facility	115 (26.6%)	6 (1.4%)	25.1%	15.4%,34.9%	<0.001	134 (34.0%)	92 (22.3%)	11.7%	4.5%,19.0%	0.002
Latrine utilization										
Direct observations (Composite) ‡	-	-	-	-	-	114 (28.9%)	147 (35.7%)	-6.7%	-15.7%,2.3%	0.14
Self-report	421 (97.2%)	374 (89.3%)	7.9%	2.5%,13.3%	0.004	378 (95.9%)	372 (90.3%)	5.6%	2.3%, 9.0%	0.001
Feces around pit hole	121 (28.7%)	157 (42.0%)	--13.2%	-31.0%,-4.5%	0.14	82 (21.9%)	83 (22.4%)	-0.5%	-6.8%,5.8%	0.87
Feces in the compound	20 (4.6%)	21 (5.0%)	-0.4%	-4.0%,3.2%	0.83	10 (2.5%)	18 (4.4%)	-1.8%	-4.7%,1.0%	0.20
Feces outside compound	12 (2.8%)	16 (3.8%)	-1.0%	-3.5%,1.4%	0.41	7 (1.8%)	11 (2.7%)	-0.9%	-2.9%,1.1%	0.39
Fly number										
Child feces disposal	413 (97.6%)	376 (93.3%)	4.3%	-0.8%, 9.5%	0.10	-	-	-	-	-
Reported Handwashing at five critical times§						128 (32.5%)	126 (30.6%)	1.90%	-5.9%, 9.7%	0.63

* An improved latrine was defined as having a pit deeper than 2 meters, a pit-hole cover, slab, wall, door, roof, and a handwashing facility with soap; latrine depth was not measured at the 5-month follow-up, and thus the proportion of improved latrines was not assessed

†A partially improved latrine was defined as having a pit, a pit-hole cover, and slab: this row includes both improved and partially improved latrines.

‡ The absence of spider webs, worn path, and odor were assessed at the 3-month follow up, but inappropriately coded in a mutually exclusive way, and thus we excluded the results.

§See S5 Table for results on handwashing behavior at the respective times; handwashing at five critical times was assessed at the 3-month follow-up, but inappropriately coded in a mutually exclusive way, and thus we excluded the results.

Table S6. Secondary and intermediate outcomes at 3, 5 and 9 months (cont'd)

Survey period	9 months				
	Intervention	Control	Risk Difference /Rate Ratio	95% CI	p
Outcomes	418	451			
Having a household latrine					
All types	415 (99.3%)	410 (90.9%)	8.4%	3.4%, 13.3%	0.001
Improved latrine	148 (35%)	20 (4.4%)	31.0%	19.8%,42.1%	<0.001
Partially improved latrine or better†	281 (67%)	85 (18.8%)	48.4%	37.3%,59.5%	<0.001
Hand washing facility	197 (47.1%)	45 (10.0%)	37.3%	23.6%,51.0%	<0.001
Latrine utilization					
Direct observations (Composite)	156 (37.3%)	170 (37.7%)	-1.4%	-24.6%,21.8%	0.90
Self-report	415 (99.3%)	410 (90.9%)	8.4%	3.4%,13.3%	0.001
Feces around pit hole	83 (20.0%)	98 (23.9%)	-3.9%	-23.5%,15.6%	0.70
Feces in the compound	6 (1.4%)	34 (7.5%)	-6.1%	-11.4%,-0.8%	0.03
Feces outside compound	2 (0.5%)	29 (6.4%)	-6.0%	-11.1%,-0.8%	0.02
Fly number	5.9 (10.2)	12.6 (15.0)	0.60	0.45, 0.78	<0.001
Child feces disposal	414 (99.0%)	405 (89.8%)	5.1%	-0.1%,10.3%	0.06
Reported Handwashing at five critical times	165 (39.5%)	160 (35.5%)	4.00%	-18.2%, 26.2%	0.73

Table S7. Secondary and intermediate outcomes at 3, 5, 9, and 10 months

Survey period	3 months					5 months				
	Intervention	Control	Relative Risk	95% CI	p	Intervention	Control	Relative Risk	95% CI	p
Outcomes	433	419				394	412			
Having a household latrine All types	421 (97.2%)	374 (89.3%)	1.09	1.03,1.15	0.002	374 (94.9%)	370 (89.8%)	1.06	1.02,1.10	0.002
Improved latrine*	115 (26.6%)	6 (1.4%)	15.66	5.31,46.18	<0.001	-	-			
Partially improved latrine or better†	236 (54.5%)	56 (13.4%)	3.63	2.40,5.50	<0.001	203 (51.5%)	144 (35.0%)	1.40	1.21,1.62	<0.001
Hand washing facility	115 (26.6%)	6 (1.4%)	16.17	5.40,48.39	<0.001	134 (34.0%)	92 (22.3%)	1.52	1.17,1.96	0.002
Latrine utilization										
Direct observations (Composite)						114 (28.9%)	147 (35.7%)	0.79	0.60,1.03	0.09
Self-report	421 (97.2%)	374 (89.3%)	1.09	1.03,1.15	0.003	378 (95.9%)	372 (90.3%)	1.06	1.03,1.10	0.001
Feces around pit hole	121 (28.7%)	157 (42.0%)	0.67	0.44,1.03	0.07	82 (21.9%)	83 (22.4%)	0.99	0.75,1.32	0.96
Feces in the compound	20 (4.6%)	21 (5.0%)	0.89	0.41,1.91	0.76	10 (2.5%)	18 (4.4%)	0.60	0.26,1.36	0.22
Feces outside compound	12 (2.8%)	16 (3.8%)	0.74	0.36,1.53	0.42	7 (1.8%)	11 (2.7%)	0.67	0.27,1.71	0.41
Child feces disposal	413 (97.6%)	376 (93.3%)	1.11	1.01,1.21	0.03	-	-	-	-	-
Reported Handwashing at five critical times§						128 (32.5%)	126 (30.6%)	1.06	0.84,1.35	0.62

* An improved latrine was defined as having a pit deeper than 2 meters, a pit-hole cover, slab, wall, door, roof, and a handwashing facility with soap; latrine depth was not measured at the 5-month follow-up, and thus the proportion of improved latrines was not assessed

†A partially improved latrine was defined as having a pit, a pit-hole cover, and slab: this row includes both improved and partially improved latrines.

‡ The absence of spider webs, worn path, and odor were assessed at the 3-month follow up, but inappropriately coded in a mutually exclusive way, and thus we excluded the results.

§See S5 Table for results on handwashing behavior at the respective times; handwashing at five critical times was assessed at the 3-month follow-up, but inappropriately coded in a mutually exclusive way, and thus we excluded the results.

Table S7. Secondary and intermediate outcomes at 3, 5, 9, and 10 months (cont'd)

Survey period	9 months					10 months				
	Intervention	Control	Relative Risk	95% CI	p	Intervention	Control	Relative Risk	95% CI	p
Outcomes	418	451				439	426			
Having a household latrine All types	415 (99.3%)	410 (90.9%)	1.09	1.03,1.15	0.002	437 (99.5%)	387 (90.8%)	1.10	1.04,1.15	<0.002
Improved latrine	148 (35%)	20 (4.4%)	5.93	2.80,12.57	<0.001	154 (35.0%)	12 (2.8%)	10.46	4.21,25.95	<0.001
Partially improved latrine or better†	281 (67%)	85 (18.8%)	2.93	1.99,4.31	<0.001	302 (69.0%)	64 (15.0%)	3.91	2.67,5.75	<0.001
Hand washing facility	197 (47.1%)	45 (10.0%)	3.93	2.09,7.40	<0.001	207 (47.2%)	49 (11.5%)	4.28	2.41,7.58	<0.001
Latrine utilization (direct observations)										
Direct observations (Composite)	156 (37.3%)	170 (37.7%)	0.92	0.52,1.63	0.76	162 (36.9%)	191 (44.8%)	0.77	0.45,1.33	0.35
Self-report	415 (99.3%)	410 (90.9%)	1.09	1.03,1.15	0.002	437 (99.5%)	387 (90.9%)	1.09	1.04,1.15	<0.001
Feces around pit hole	83 (20.0%)	98 (23.9%)	0.59	0.26,1.32	0.20	63 (14.4%)	100 (25.8%)	0.52	0.21,1.33	0.18
Feces in the compound	6 (1.4%)	34 (7.5%)	0.20	0.06,0.65	0.007	7 (1.6%)	30 (7.4%)	0.18	0.04,0.74	0.02
Feces outside compound	2 (0.5%)	29 (6.4%)	0.08	0.02,0.38	0.001	5 (1.1%)	24 (5.6%)	0.17	0.05,0.58	0.005
Child feces disposal	414 (99.0%)	405 (89.8%)	1.10	1.03,1.18	0.004	436 (99.3%)	384 (90.10%)	1.10	1.04,1.16	<0.001
Reported Handwashing at five critical times	165 (39.5%)	160 (35.5%)	1.06	0.66,1.69	0.82	194 (44.2%)	143 (33.6%)	1.40	0.82,2.37	0.22

Table S8. Effects on handwashing behavior

survey period			3 months					5 months		
	intervention	***control***	RD	95% CI	p	***intervention***	***control***	RD	95% CI	p
secondary outcomes	***433***	***419***				***394***	***412***			
handwashing after defecation	359 (82.9%)	308 (73.5%)	9.40%	-5.1%, 23.9%	0.2	316 (80.2%)	329 (79.9%)	0.30%	-6.9%,7.6%	0.93
handwashing before eating	415 (95.8%)	376 (89.7%)	6.10%	-0.4%, 12.6%	0.07	381 (96.7%)	392 (95.2%)	1.60%	-1.0%,4.1%	0.23
handwashing before food preparation						237 (60.2%)	241 (58.5%)	1.70%	-7.1%, 10.4%	0.71
handwashing before child buttocks cleaning						259 (65.7%)	256 (62.1%)	3.60%	-3.9%, 11.1%	0.35
handwashing before feeding						301 (76.4%)	306 (74.3%)	2.10%	-4.4%, 8.6%	0.52
handwashing all critical times						128 (32.5%)	126 (30.6%)	1.90%	-5.9%, 9.7%	0.63

			9 months					10 months		
	intervention	***control***	RD	95% CI	p	***intervention***	***control***	RD	95% CI	p
secondary outcomes	418	451				439	426			
handwashing after defecation	304 (72.7%)	348 (77.2%)	-4.4%	-23.7%,14.9%	0.65	359 (81.8%)	344 (80.8%)	1.0%	-16.0%, 18.1%	0.91
handwashing before eating	415 (99.3%)	408 (90.5%)	8.80%	1.0%, 16.6%	0.03	430 (98.0%)	379 (89.0%)	9.0%	-2.8%, 20.8%	0.14
handwashing before food preparation	255 (61.0%)	269 (60.0%)	1.40%	-20.2%, 22.9%	0.9	270 (61.5%)	239 (56.1%)	5.4%	-18.0%, 28.8%	0.65
handwashing before child buttocks cleaning	312 (74.6%)	294 (65.2%)	9.50%	-9.2%, 28.2%	0.32	357 (81.3%)	296 (69.5%)	11.8%	-7.4%,31.1%	0.23
handwashing before feeding	344 (82.3%)	330 (73.2%)	9.10%	-4.2%, 22.4%	0.18	387 (88.2%)	300 (70.4%)	17.7%	5.0%, 31.4%	0.006

handwashing all critical times	165 (39.5%)	160 (35.5%)	4.00%	-18.2%, 26.2%	0.73	194 (44.2%)	143 (33.6%)	10.6%	-12.6%, 33.8%	0.37

Table S9. Comparison of feces around pit-hole and fly counts between latrine type in treatment arm between those with an improved versus an unimproved latrine

		presence of feces around pit hole	fly counts
3 months	unimproved	94/306 (30.7%)	N/A
	improved	27/115 (23.5%)	
5 months	unimproved	N/A	N/A
	improved		
9 months	unimproved	62/267 (23.2%)	11.0(14.1)
	improved	21/148 (14.2%)	2.5(4.6)
10 months	unimproved	52/283 (18.4%)	6.6(8.0)
	improved	11/154 (7.1%)	1.8(3.8)

Table S10. CONSORT 2010 checklist of information to include when reporting a CRT

Section/Topic	Item No	Standard Checklist item	Extension for cluster designs	paragraph numbers per section
Title and abstract				
	1a	Identification as a randomised trial in the title	Identification as a cluster randomised trial in the title	Title, paragraph 1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	See table 2	Abstract
Introduction				
Background and objectives	2a	Scientific background and explanation of rationale	Rationale for using a cluster design	Background, Paragraph 4 Methods- Randomization and Masking Paragraph 1
	2b	Specific objectives or hypotheses	Whether objectives pertain to the cluster level, the individual participant level or both	Background, Paragraph 6
Methods				
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	Definition of cluster and description of how the design features apply to the clusters	Methods- Study design, Paragraph 1
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons		Not Applicable
Participants	4a	Eligibility criteria for participants	Eligibility criteria for clusters	Methods- participants, Paragraph 1
	4b	Settings and locations where the data were collected		Methods- Study settings, Paragraph 1
Interventions	5	The interventions for each group with sufficient details to allow replication, including	Whether interventions pertain to the cluster level, the individual participant level or both	Methods- Procedures, Paragraph 1-6

		how and when they were actually administered		
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	Whether outcome measures pertain to the cluster level, the individual participant level or both	Methods-Outcomes, Paragraph 1-2
	6b	Any changes to trial outcomes after the trial commenced, with reasons		Not Applicable
Sample size	7a	How sample size was determined	Method of calculation, number of clusters(s) (and whether equal or unequal cluster sizes are assumed), cluster size, a coefficient of intracluster correlation (ICC or *k*), and an indication of its uncertainty	Methods-Statistical analysis, Paragraph 1-2
	7b	When applicable, explanation of any interim analyses and stopping guidelines		Not Applicable
Randomisation:				
Sequence generation	8a	Method used to generate the random allocation sequence		Methods-Randomization and masking, Paragraph 1
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	Details of stratification or matching if used	Methods-Randomization and masking, Paragraph 1
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	Specification that allocation was based on clusters rather than individuals and whether allocation concealment (if any) was at the cluster level, the individual participant level or both	Methods- Study design and participants, Paragraph 2 Methods-Randomization and masking, Paragraph 1
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	Replace by 10a, 10b and 10c	

	10a		Who generated the random allocation sequence, who enrolled clusters, and who assigned clusters to interventions	Methods-Randomization and masking, Paragraph 1
	10b		Mechanism by which individual participants were included in clusters for the purposes of the trial (such as complete enumeration, random sampling)	Methods-Participants, Paragraph 2 Methods-Randomization and masking, Paragraph 1
	10c		From whom consent was sought (representatives of the cluster, or individual cluster members, or both), and whether consent was sought before or after randomisation	Methods-Methods-Participants, Paragraph 2
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how		Methods-Randomization and masking, Paragraph 1
	11b	If relevant, description of the similarity of interventions		Methods- Study design, Paragraph 1
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	How clustering was taken into account	Methods-Statistical analysis, Paragraph 3-4
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses		Methods-Statistical analysis, Paragraph 5
Results				
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	For each group, the numbers of clusters that were randomly assigned, received intended treatment, and were analysed for the primary outcome	Results-Figure 1-2

	13b	For each group, losses and exclusions after randomisation, together with reasons	For each group, losses and exclusions for both clusters and individual cluster members	Results-Figure 1-2
Recruitment	14a	Dates defining the periods of recruitment and follow-up		Results-Paragraph 1
	14b	Why the trial ended or was stopped		Not Applicable
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	Baseline characteristics for the individual and cluster levels as applicable for each group	Results- Baseline characteristics of participants, Paragraph 2; Table 1
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	For each group, number of clusters included in each analysis	Results-Paragraph 1
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	Results at the individual or cluster level as applicable and a coefficient of intracluster correlation (ICC or k) for each primary outcome	Results-Main effects, Paragraph 3; Table 2-3
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended		Results-Main effects, Paragraph 3; Table 2-3
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory		Results-Effects on intermediary outcomes, Paragraph 4; Table 4
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)		Results-Paragraph 5
Discussion				
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses		Discussion, Paragraph 8

Generalisability	21	Generalisability (external validity, applicability) of the trial findings	Generalisability to clusters and/or individual participants (as relevant)	Discussion, Paragraph 9-10
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence		Discussion, Paragraph 3-7
Other information				
Registration	23	Registration number and name of trial registry		Methods-Study design, Paragraph 1
Protocol	24	Where the full trial protocol can be accessed, if available		Methods-Study design, Paragraph 1
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders		Front page

Supplementary materials for the Chapter 5

Table S1. Performance of latrines on child diarrheal prevalence by type

Table S2. Comparison of performance between unimproved latrines in high- and low-coverage areas, and improved latrines in high-coverage areas and unimproved latrines in low-coverage areas (based on the coverage 50%of an improved latrine coverage)

Table S3. Detailed status of JMP improved latrines (% with the following component)

Table S1. Performance of latrines on child diarrheal prevalence by type

		Having a latrine but not up to JMP improved	Having a JMP improved latrine (a)		Presence of an improved latrine (b)	
			unadjusted	**adjusted**	**unadjusted**	**adjusted**
All	**OR**		**0.87**	**0.99**	**0.46**	**0.46**
	95% CI		**0.51-1.49**	**0.56-1.79**	**0.26-0.80**	**0.27-0.81**
	p-value		**0.62**	**0.99**	**0.006**	**0.006**
June (3 months)	n/N	25/182		75/481		8/102
	%	13.74%		15.59%		7.84%
	OR		1.75	2.05	0.27	0.26
	95% CI		0.56-5.41	0.58-7.24	0.05-1.32	0.04-1.51
	p-value		0.33	0.27	0.11	0.13
December (9 months)	n/N	1/8		75/647		8/127
	%	12.50%		11.59%		6.30%
	OR		0.91	0.86	0.50	-
	95% CI		0.00-2399.99	0.01-143.55	0.03-8.83	-
	p-value		0.98	0.95	0.64	-
January (10 months)	n/N	0/5		62/674		7/138
	%	0.0%		9.20%		5.07%
	OR			-	-	-
	95% CI			-	-	-
	p-value			-	-	-

a Reference: Those with a latrine but not up to a JMP improved latrine (adjusted for individual variables: child's age and sex, presence of improved water source, handwashing behavior at four critical times)
b Reference: Those with a JMP improved latrine (adjusted for individual variables: child's age and sex, presence of improved water source, handwashing behavior at four critical times)

Table S2. Comparison of performance between unimproved latrines in high- and low-coverage areas, and improved latrines in high-coverage areas and unimproved latrines in low-coverage areas (based on the coverage 50%of an improved latrine coverage)

		Low coverage		High coverage			Comparison of **unimproved** latrines in **high- and low-coverage areas (herd protection)**			Comparison of **improved latrine in high-coverage areas** and **unimproved latrine in low-coverage areas**		
		Absence of a latrine	Presence of a latrine, but not an improved one	Absence of a latrine	Presence of a latrine, but not an improved one	Improved latrine	OR	95% CI	p-value	OR	95% CI	p-value
All							**0.30**	**0.06-1.61**	**0.16**	**0.32**	**0.08-1.30**	**0.11**
June	n/N	10/57	100/646	0	0/17	3/37	0.50	0.24-1.06	0.07	0.59	0.20-1.77	0.35
	%	17.5%	15.5%		0.0%	8.1%						
December	n/N	9/42	75/631	0	1/24	4/63	0.43	0.05-3.55	0.43	0. 37	0.08-1.67	0.20
	%	21.4%	11.9%		4.2%	6.4%						
January	n/N	7/40	59/626		3/53	3/105	0.78	0.20-3.04	0.72	0.19	0.01-2.43	0.20
	%	17.5%	9.4%	0	5.8%	2.9%						

Table S3. Detailed status of JMP improved latrines (% with the following component)

	Drop-hole cover	wall	roof	door	2 or more
3 months	48.5%	77.0%	66.6%	42.2%	61.0%
9 months	45.5%	83.1%	73.4%	56.6%	52.1%
10 months	44.8%	83.1%	74.8%	56.2%	51.2%

Supplementary materials for the Chapter 6

Table S1. Parameter distribution and justification

Table S2. Parameter values (base case)

Table S3. Benefits and costs reflecting slippage (average annual reduction: 3.5%) (present value in 2016, Int'l$)

Table S4. Benefits and costs reflecting the population growth of 2.7% (present value in 2016, Int'l$)

Table S5. Benefits and costs reflecting the treatment and transportation costs reported by caregivers (present value in 2016, Int'l$)

Figure S1. Distribution of benefits by item

Figure S2. Distribution of benefits by age group

Text S1. Comparisons of the interventions between the intervention and the control groups

Text S2. Lifetime of an improved latrine in this study

Table S1. Parameter distribution and justification

parameter	parameter values				
	base case	low	high	distribution for probabilistic sensitivity analysis	justification
Effect of CLTS on longitudinal prevalence of child diarrhea (Reduced days of child diarrhea per year)*	1.6	0.2	2.6	normal	point estimate and 95% CI from the trial
Life-span (years)	10	5	15	N/A	base case: reference, mean value: 10.0, standard deviation: 1.7
Value of Statistical Life (VSL, Int'l$)	45,194	27,094	66,141	lognormal	base case, low and high values: Radin M et al. [16], Robinson LA et al. [26]
Discount rate (%)	3	0	8	N/A	base case, low and high values: Drummond MF et al. [10]
Income growth (%)	2	0	4	uniform distribution	base case: reference, low and high values represent +/-100% of base case estimate.
Hourly income (Int'l$)	0.67	0.39	0.5	normal	point estimate and 95% CI from the trial
Value of time (5-14 years, %)	25	0	50	N/A	base case: reference, mean value: 25.0, standard deviation: 8.3
Value of time (>14 years, %)	50	25	75	N/A	base case: reference, mean value: 50.0, standard deviation: 8.3
Case Fatality Rate (CFR, <5 years, %)	0.07	0.05	0.09	normal	point estimate and 95% CI from the Global Burden of Disease study
CFR(5-14 years, %)	0.02	0.01	0.03	normal	point estimate and 95% CI from the Global Burden of Disease study
CFR(>14 years, %)	0.03	0.02	0.05	normal	point estimate and 95% CI from the Global Burden of Disease study
Operation & Maintenance (O&M, %)	10	5	15	N/A	base case: reference, low and high values represent +/-50% of base case estimate.
Education (%)	10	5	15	N/A	base case: reference, low and high values represent +/-50% of base case estimate.

Table S2. Parameter values (base case)

Age Group	Parameters	Unit	Value	Data source
Overall	Number of villages	village	24	Trial data
	Improved latrine uptake (intervention group)	%	35.0	Trial data
	Households in the intervention group	households	1,737	Trial data
	Number of children (<5)	person	1,301	Trial data
	Number of children (5-14)	person	3,804	Trial data
	Number of adults (≥15)	person	4,608	Trial data
	Discount rate	%	3	Reference [16]3
	Annual income growth	%	2	Reference [33]
	VSL(Value of Statistical Life)	Int'l $	45,194	Reference [29,32,33]
	Useful life of an improved latrine	years	10	Reference [39,40]
	Operation & Maintenance cost (proportion of annualized cost of initial investment)	%	10	Reference [38]
	Time constructing a latrine (per household)	hours	120	Trial data
	Diarrhea case fatality rate (<5)	%	0.07	Reference [31]
	Diarrhea case fatality rate (5-14)	%	0.02	Reference [31]
	Diarrhea case fatality rate (≥15)	%	0.03	Reference [31]
Children (<5)	Proportion of children with diarrhea whose caregivers sought care	%	62.8	Trial data
	Proportion of children with diarrhea taken to health facilities	%	56.1	Trial data
	Proportion seeking treatment from drug store	%	2.0%	Trial data
	Proportion seeking treatment from a traditional healer	%	1.0%	Trial data
	Proportion of health facility careseekers becoming outpatients	%	50.9	Trial data

3 Reference in the chapter 6.

Age Group	Parameters	Unit	Value	Data source
	Proportion of health facility careseekers becoming inpatients	%	5.2	Trial data
	Average days of hospitalization (per case)	days	5.0	Trial data
	Caregiver lost days due to home care for a child with diarrhea	days	1	Trial data
	Number of diarrhea cases avoided per year (under-5 children)	daily episodes	1.6	Trial data
	Treatment cost (health facilities)	Int'l$	0.70	Trial data
	Treatment cost (drug stores)	Int'l$	0.55	Trial data
	Treatment cost (traditional healers)	Int'l$	0.25	Trial data
	Meal cost	Int'l$	0.20	Trial data
	Transportation cost (round trip)	Int'l$	0.75	Trial data
	Accommodation cost (inpatient)	Int'l$	3.66	Trial data
Other groups (5-14 or ≥15)	Proportion of diarrhea patients whose caregivers sought care (or who sought care themselves)	%	45.40	Trial data
	Proportion of diarrhea patients taken to health facilities	%	34.69	Trial data
	Proportion seeking treatment from drug store	%	5.61	Trial data
	Proportion seeking treatment from a traditional healer	%	6.12	Trial data
	Proportion of health facility careseekers becoming outpatients	%	32.40	Trial data
	Proportion of health facility careseekers becoming inpatients	%	2.29	Trial data
	Average days of hospitalization (per case)	Days	3.50	Trial data
	Caregiver lost days due to home care for a child with diarrhea	Days	1	Trial data
	Treatment cost (health facilities)	Int'l$	0.70	Trial data
	Treatment cost (drug stores)	Int'l$	0.55	Trial data
Other groups (5-14 or ≥15)	Treatment cost (traditional healers)	Int'l$	0.25	Trial data
	Meal	Int'l$	0.30	Trial data
	Transportation cost (round trip)	Int'l$	1.49	Trial data
	Accommodation cost	Int'l$	7.32	Trial data
	Hourly income (before application of valuation percentages)	Int'l$	0.67	Trial data

Age Group	Parameters	Unit	Value	Data source
	Switched from open defecation to a household latrine (5-14)	%	2.85	Trial data
	Switched from open defecation to a household latrine (≥15)	%	4.18	Trial data
	Switched from a communal latrine to a household latrine (5-14)	%	3.65	Trial data
	Switched from a communal latrine to a household latrine (≥15)	%	2.95	Trial data
	Switched from a neighbor's latrine to a household latrine (5-14)	%	48.99	Trial data
	Switched from a neighbor's latrine to a household latrine (≥15)	%	20.35	Trial data
	Saved time from the switch (open defecation, round trip)	minutes	9.13	Trial data
	Saved time from the switch (a communal latrines, round trip)	minutes	10.00	Trial data
	Saved time from the switch (a neighbor's latrine, round trip)	minutes	4.50	Trial data
	Number of diarrhea cases avoided per year (5-14)	daily episodes	0.42	Trial data
	Number of diarrhea cases avoided per year (≥15)	daily episodes	0.33	Trial data

Table S3. Benefits and costs reflecting slippage (average annual reduction: 3.5%) (present value in 2016, Int'l$)

Item			Age group <5	5-14	≥15	Sum	%
Benefits	Avoided diarrhea cases	Treatment costs saved	2,746	1,088	1,025	4,859	13%
		Transportation costs saved	2,822	1,927	1,816	6,565	
		Meal costs saved	753	388	366	1,506	
		Accommodation costs saved	281	81	108	470	
		Time saved for intensive care	42,903	16,935	31,911	91,748	
		Time saved from health professionals	52,213	10,340	9,742	72,295	
		Sum	101,718	30,759	44,968	177,443	
	Averted premature deaths	Value of statistical life	506,440	114,232	161,438	782,109	58%
	Time saved from increased accessibility	Switch from open defecation		27,737	98,558	126,296	29%
		Switch from using communal latrines		38,908	76,185	115,093	
		Switch from using neighbors' latrines		78,333	78,832	157,165	
		Sum		144,978	253,575	398,554	
	Grand total		608,158 (45%)	289,969 (21%)	459,981 (34%)	1,358,106 (100%)	100%
Costs	Initial costs						
	Project implementation & management	Recurrent				223,845	54%
		Capital				14,580	
		Sum				238,425	
	Investment of community members and local stakeholders	Recurrent				102,353	42%
		Capital				84,337	
		Sum				186,690	
	Sum of initial costs					425,115	
	Operation & management	Operation & management				8,245	4%
	Education for the lifespan of a latrine	Education				8,245	
		Sum				16490	
	Grand total					441,605	100%
Benefit-Cost Ratio			**3.1**				
Net Present Value			**916,500 (38,188 per community; 528 per household)**				

Table S4. Benefits and costs reflecting the population growth of 2.7%* (present value in 2016, Int'l$)

Item			Age group <5	5-14	≥15	Sum	%
Benefits	Avoided diarrhea cases	Treatment costs saved	3,800	1,506	1,419	6,725	13%
		Transportation costs saved	3,906	2,667	2,513	9,086	
		Meal costs saved	1,042	537	506	2,085	
		Accommodation costs saved	389	111	150	650	
		Time saved for intensive care	59,986	23,678	44,617	128,281	
		Time saved from health professionals	73,003	14,457	13,621	101,082	
		Sum	142,126	42,956	62,826	247,909	
	Averted premature deaths	Value of statistical life	708,096	159,717	225,720	1,093,533	58%
	Time saved from increased accessibility	Switch from open defecation		38,782	137,803	176,584	29%
		Switch from using communal latrines		54,400	106,521	160,921	
		Switch from using neighbors' latrines		109,524	110,222	219,745	
		Sum		202,706	354,546	557,250	
	Grand total		850,222 (45%)	405,379 (21%)	643,092 (34%)	1,898,692 (100%)	100%
Costs	Initial costs						
	Project implementation & management	Recurrent				223,845	54%
		capital				14,580	
		sum				238,425	
	Investment of community members and local stakeholders	Recurrent				102,353	42%
		capital				84,337	
		sum				186,690	
	Sum of initial costs					425,115	
	Operation & management	Operation & management				9,892	4%
	Education for the lifespan of a latrine	Education				9,892	
		Sum				19,784	
	Grand total					444,899	100%
Benefit-Cost Ratio			**4.3**				
Net Present Value			**1,453,794 (60,575 per community; 837 per household)**				

(*source, United Nations Population Division. World Population Prospects)

Table S5. Benefits and costs reflecting the treatment and transportation costs reported by caregivers* (present value in 2016, Int'l$)

Item			Age group <5	5-14	≥15	Sum	%
Benefits	Avoided diarrhea cases	Treatment costs saved	30,307	10,584	9,972	50,863	15%
		Transportation costs saved	3,566	2,312	2,718	8,056	
		Meal costs saved	1,042	537	506	2,085	
		Accommodation costs saved	389	111	150	650	
		Time saved for intensive care	59,986	23,678	44,617	128,281	
		Time saved from health professionals	73,00,3	14,457	13,621	101,082	
		Sum	168,293	51,679	71,584	291,017	
	Averted premature deaths	Value of statistical life	708,096	159,717	225,720	1,093,533	56%
	Time saved from increased accessibility	Switch from open defecation		38,782	137,803	176,584	29%
		Switch from using communal latrines		54,400	106,521	160,921	
		Switch from using neighbors' latrines		109,524	110,222	219,745	
		Sum		202,706	354,546	557,250	
	Grand total		876,389 (45%)	414,102 (21%)	651,850 (34%)	1,941,800 (100%)	100%
Costs	Initial costs						
	Project implementation & management	Recurrent				223,845	54%
		capital				14,580	
		sum				238,425	
	Investment of community members and local stakeholders	Recurrent				102,353	42%
		capital				84,337	
		sum				186,690	
	Sum of initial costs					425,115	
	Operation & management	Operation & management				9,892	4%
	Education for the lifespan of a latrine	Education				9,892	
		Sum				19,784	
	Grand total					444,899	100%
Benefit-Cost Ratio			**3.8**				
Net Present Value			**1,239,001 (51,625 per community; 713 per household)**				

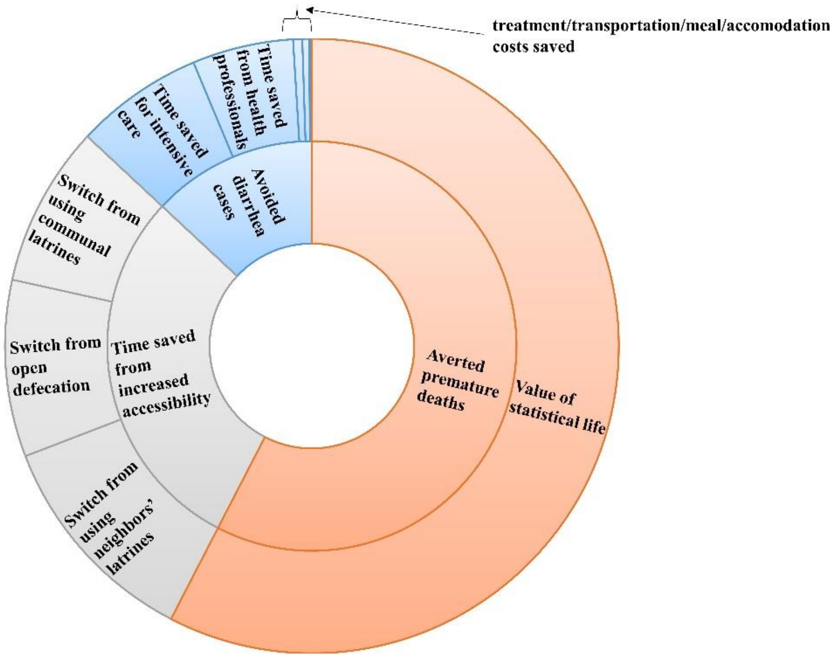

Figure S1. Distribution of benefits by item

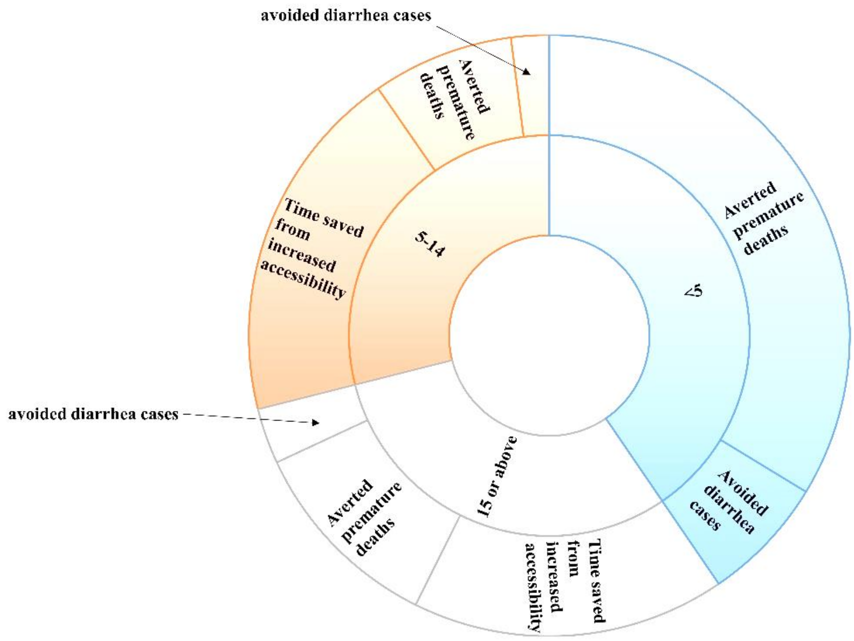

Figure S2. Distribution of benefits by age group

Text S1. Comparisons of the interventions between the intervention and the control groups

Although the Ethiopian government adopted nationwide sanitation improvement policy (Community Led Total Sanitation & Hygiene) in 2008, the programme has not been carried out in many districts due to lack of resources.

In response to this, the Ethiopian government launched a large-scale CLTSH programme in 2012-2015 in the SNNPR, Amhara, Tigray, and Oromia states of the country in collaboration with UNICEF and Global Sanitation Fund.[1] Eighty-six (86) districts in these states benefited CLTSH programme for the first time. The SNNPR State comprises 15 zones (an administrative unit below State) and 77 districts. The Gurage zone where the Cheha and Enemor Ena Ener districts belong to was not included in the intervention area.[1] These districts were classified as a control area in the evaluation to investigate the effect of the CLTSH programme.[1]

The Ethiopian government submitted the proposal of the KOICA WASH project in 2013 and the target areas of the project were selected among the districts that had no previous intervention of the CLTSH.[2] The SNNPR state has been implementing CLTS program in 8 districts since 2009 but the Cheha and Enemore Ena Ener districts were not included in the target dirstricts.[3]

According to the two project managers of the KOICA CLTS intervention, one of them is a former deputy director of District Health Office, CLTS interventions had never been implemented in the two target districts, and no HEWs had been trained on CLTS prior to the intervention (Individual communication between January 5-18, 2019). The local project manager and former deputy director stated that there was no budget allocated to sanitation improvements in the two districts.

However, we estimated how much budget is being indirectly allocated to sanitation improvement at the district and the village level on the basis of published reports. In a decentralized system, the director of district health office is the key figure responsible for spearheading sanitation and hygiene promotion throughout the district.[4] The Health Extension Workers (HEWs) have the main responsibility of sanitation improvements in their catchment area as a front-line government official, and they were charged with 16 key tasks. Most health posts in rural areas of Ethiopia are staffed by two HEWs, and they serve an average population of 5,000 individuals.[5] There were some studies examining HEWs' time allocation on their billable activities (i.e. the user of the activities, an individual or a community, was identifiable).[5-8] The time spent on different activities by HEWs in Ethiopia was estimated in 2014 in the Health Extension Workers Time Motion Study across 22 districts in Ethiopia. The study suggested that HEWs spent 1600 minutes on billable activities per month, and roughly 25% of total encounters, referring to each discrete time an activity was performed, were spent on hygiene and environmental sanitation education or services for rural HEWs (Table 1 of Text S1).[6] They spent 51% of their time at the health post, 15% in community outreach and 13% visiting households.[5] Based on the results of the studies, we calculated how many minutes and costs are being spent on hygiene and environmental sanitation education or services (Table 2 of Text S1).

Given that an average monthly cost of rural HEWs for hygiene and environmental sanitation education/services including supplies, supervisor salary and other overhead cost was US$88.4 for rural HEWs and there were 2 HEWs per health post covering a sub-district, and 48 health posts exist in the two districts, we estimate that US$50,918 was being spent on sanitation improvements in the two districts (Table 3 of Text S1). Finally, we estimate that US$5,764 was spent on sanitation improvements both in intervention and control arms in terms of HEWs activities.

According to recent reports,[9-11] the Ethiopian government spent 0.006% of GDP on sanitation in 2014. The GDP was 43,311 million US$, which means the Ethiopian government spent US$2,598,660 on sanitation across the country. Dividing this by 770 districts of Ethiopia, we estimate that one district expended US$3374 on sanitation improvements, and US$764 was spent on sanitation in 24 Gotts by the government.

The key activities for sanitation improvements and budgets in the intervention and the control arms are described in Table 3. Although these are indirect and preliminary estimates on government expenditures, and need to be verified with the local government, the incremental cost of the CLTS intervention in the 24 Gotts would remain same because CLTS activities were carried out only in the intervention group.

Table 1 of Text S1. Health education and service cost scale among rural HEWs in Ethiopia (source: Canavan ME, et al., 2017)

HEW-Provided education and services in Households and Health Posts	**Percentage and duration of average encounter**		**Base salary per encounter (US$)**	**Total cost per encounter (270% non-salary rate) (US$)**
	Percentage breakdown of encounter across 12 HEWs	**Average time/ Encounter (minutes)**		
Hygiene and environmental sanitation education/services[a]	**25.4**	**12.9**	**0.74**	**2.72**
Family health services				
Provide contraceptives	14.2	7.9	0.45	1.66
Provide antenatal and postnatal care	6.3	20.5	1.17	4.32
Provide care for sick and healthy children	5.8	15.9	0.90	3.35
Provide vaccinations	15.4	11.3	0.65	2.39
Provide nutrition education/services	5.9	18.1	1.03	3.82
Provide other health education	10.4	14.1	0.80	2.98
Disease prevention and control				
Provide education/services on HIV/AIDS	0.8	27.8	1.59	5.87

HEW-Provided education and services in Households and Health Posts	**Percentage and duration of average encounter**		**Base salary per encounter (US$)**	**Total cost per encounter (270% non-salary rate) (US$)**
	Percentage breakdown of encounter across 12 HEWs	**Average time/ Encounter (minutes)**		
Provide voluntary counseling and testing on HIV	0.2	47.3	2.70	9.97
Test, educate and provide malaria treatment	10.1	16.6	0.95	3.50
First-aid education and referral	1.4	9.2	0.52	1.94
Provide TB related services	1.9	4.2	0.24	0.89
Screening and education for non-communicable diseases	1.3	6.1	0.35	1.30
Group training (i.e. Women's Development Army)	1.0	99.3	5.66	20.94

[a] The category of 'providing health education and services' is narrowly defined as the direct education and care provided in delivering the 16 HEW service packages, usually in the health post or at the household level. Hygiene and environmental sanitation education/services includes: **Solid and liquid waste disposal; Water supply safety measures; Control of insects and rodents; Food hygiene and safety; Personal hygiene; Healthy home environment; Construction and maintenance of sanitary latrines**. Budget for sanitation improvements was not separated out, and thus this figure may be interpreted as a maximum value.

[b] This is rough and indirect estimates. The details of the budget allocation was not articulated in the published reports and it might be to some extent duplicated with the budget allocated to Hygiene and environmental sanitation education/services by HEWs.

Table 2 of Text S1. Monthly costs and time for key activities of rural HEWs in Ethiopia (estimated on the basis of Canavan ME and et al.'s study)

HEW-Provided education and services in Households and Health Posts	Percentage and duration of average encounter		Base salary /month (US$)	Total cost/ month (US$)
	Number of encounters	Total time /month (minutes)		
Hygiene and environmental sanitation education/services	**32**	**419.2**	**24.0**	**88.4**
Family health services	0	0.0	0.0	0.0
Provide contraceptives	18	143.5	8.2	30.2
Provide antenatal and postnatal care	8	165.2	9.4	34.8
Provide care for sick and healthy children	7	118.0	6.7	24.9
Provide vaccinations	20	222.7	12.8	47.1
Provide nutrition education/services	8	136.6	7.8	28.8
Provide other health education	13	187.6	10.6	39.7
Disease prevention and control	0	0.0	0.0	0.0
Provide education/services on HIV/AIDS	1	28.5	1.6	6.0
Provide voluntary counseling and testing on HIV	0	12.1	0.7	2.6
Test, educate and provide malaria treatment	13	214.5	12.3	45.2
First-aid education and referral	2	16.5	0.9	3.5
Provide TB related services	2	10.2	0.6	2.2
Screening and education for non-communicable diseases	2	10.1	0.6	2.2
Group training (i.e. Women's Development Army)	1	127.1	7.2	26.8

Table 3 of Text S1. Sanitation improvement activities and budgets in the two arms (Government routine activities and the CLTS interventions)

		activities	Intervention		Control	
			yes/no	budget (US$)	yes/no	budget (US$)
Government routine activities		Hygiene and sanitation education by Health Extension Workers (HEWs)	yes	5764[a]	yes	5764
		Sanitation expenditures	yes	764[b]	yes	764
	Sum			6528		6528
CLTS (KOICA)	Total		yes	238425*	no	0
	Grand total					

*project implementation and management cost (initial cost)

References

1. BDS. Outcome evaluation of community-led total sanitation and hygiene. Addis Ababa: BDS-Center for Development Research; 2016.

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Text S2. Lifetime of an improved latrine in this study

The lifetime of a latrine has been suggested by many organizations to range from 2 years for simple pit latrine to 20 years for an improved pit latrine [1-3]. While World Bank reports do not describe the rationale for the estimated lifespan of a latrine, the WHO and UNICEF reports estimate it based on pit volume or depth. The World Bank reports estimated lifespans of 2-4 years for a simple pit latrine and 10-20 years for an improved latrine. The WHO estimates a 20-year lifespan for a ventilated improved pit latrine. The lifespan of a pit latrine is often calculated based on the accumulation rate of fecal waste or sludge (n=v/rP: n, lifespan; v, pit volume; P, the number of users; r, accumulation rate) [4]. The accumulation rate ranges from 0.02 to 0.09 (m^3/person/year) [5]. Estimating the lifespan solely based on the pit space or pit depth is not sufficient because other factors affect latrine durability, such as geological and climatic factors, as well as the materials of latrine structure. Several other factors also affect pit latrine filling such as throwing rubbish into latrines [6], water inflows [7], flooding [8], cleaning time [8], and degradation/decomposition [9]. The definition of an improved latrine in this study (i.e., a latrine equipped with a pit deeper than 2 meters, slab, pit-hole, wall, door, roof, and handwashing facility) is stricter than that of the JMP. Correspondingly, considering the widely accepted parameter values for the lifespan of latrines by type, 10 years for an improved latrine in this study is not an overestimated value, even when taking the possible abandonment rate into account.

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Appendix 1. Water, Sanitation, and Hygiene Project in Gurage Zone, Ethiopia household Questionnaire

ውሃ፣የአካባቢ ንፅህና እና የግል ንፅህና በጉራጌ ዞን ፣ደቡብ ክልል ኢትዮጵያ የቤተሰብ መጠይቅ

Water, Sanitation, and Hygiene Project in Gurage Zone, SNNPR, Ethiopia

ውሃ፣የአካባቢ ንፅህና እና የግል ንፅህና በጉራጌ ዞን ፣ደቡብ ክልል ኢትዮጵያ

<u>Informed Consent//የፈቃደኝነት ማረጋገጫ ንባብ</u>

Good morning/afternoon.

My name is ………..…………………….. and I am a part of the team undertaking a data collection exercise in this community on behalf ofKorea InternationalCooperation Agency (KOICA). KOICAis implementing a project in EnemoreEnaEnerWoreda and ChehaWoreda to improve the Water, Sanitation and Hygiene status. I would like to ask you a number of questions about the water, sanitation and hygienestatus in this Gott and I would be grateful if you can take some time to answer them. You are under no obligation to answer any of the questions. For your information, the survey will be carried out 10 times for the following one year to assess how the project will affect your child's health status. If you choose to participate, nothing you say will be used against you under any circumstances.I also assure that the information you give will be used solely for the purposes of the project and your identity will be kept confidential.Your cooperation for the survey will significantly contribute to improvement of child health of the community. I sincerely appreciate your time and efforts invested in the survey.

እንደምንአደርክ/ሽ/እንደምንዋልክ/ሽ፡፡ስሜ--------------------------------እና እኔ በዚህ አካባቢበ ኮሪያ ኢንተርናሽናል ኤጀንሲ በኩል መረጃ ለመሰብሰብ ከመጡት አንዱ ነኝ፡፡የኮሪያ ኢንተርናሽናል ኤጀንሲ በእነሞርና ቸሃ ወረዳ የውሃ፣ የአካባቢ እና የግል ንጽህና ላይ ተሻለ ለውጥ ለማምጣት ፕሮጀክት ቀርጾ በመንቀሳቀስ ላይ ይገኛል፡፡የተወሰነ ሰዓት ሰተኸኝ/ሰተሸኝ በውሃ፤አካባቢና የግል ንፅህና ዙሪያ በመንደራችሁ ያለውን መረጃ ብትሰጠኝ/ጪኝ በጣም ደስተኛ ነኝ፡፡ጥያቄዎቹን የመመለስ ግዴታ የለብህም/ሽም፡፡በነገራችን ላይ በዚህ አመት ብቻ 10 ጊዜ ይህ መጠይቅ ይሞላል፡፡ይህም በልጆቻችሁ ጤና ላይ ፕሮጀክቱ ያለውን ለውጥ ለማየት ይጠቅማል፡፡በዚህ ጥናት ብትሳተፍ/ፊ በአንተ/ቺላይ የሚደርስ ምንም ነገር አይኖርም፡፡በተጨማሪ አንተ/ቺ የሰጠኸንን/ሽንን መረጃ ከፕሮጀክቱ ውጭ ለሌላ ነገር አንጠቀምበትም፣የሰጠኸን/ሽን መረጃ በሙሉ በሚስጥር የሚያዝ ይሆናል፡፡

ያንተ/ያንቺ ትብብር በልጆች ጤና ላይ ከፍተኛ ለውጥ አለው፡፡

ላጠፋኸው/ሽው ጊዜ እና ለሰጠኸኝ/ሺኝ ጊዜ እናመረጃ አመሰግናለሁ፡፡

Name/ስም………..……………………..

Signature/ፊርማ………..……………………..

Date/ቀን…………………………………..**ውሃ፣ የአካባቢ ንፅህና እና የግል ንፅህና በጉራጌ ዞን ፣ደቡብ ክልል ኢትዮጵያ የቤተሰብ መጠይቅ**

***Note to the Enumerator**: This survey intends to collect data about household4 and must be administered to mother or caregiver of the child under the age of 5 years old and the household, given that the project is a gender-sensitive project. ማሳሰቢያ ለመረጃ ሰብሳቢው፡ይህ ሰርቬይ መረጃ ለመሰብሰብ ያቀደው እና ግዴታ የሚውለው በእናቶች ወይም ተንከባካቢ እናቶች ሆኖ ልጆቻቸው ከ 48 ወር በታች እና በቤተሰብ ውስጥ ላሉ መሆኑ መዘንጋት የለበትም፡፡ይህ ፕሮጀክት ፆታን ያማከለ ነው፡፡*

Survey Identification Data/የመጠይቅ መለያ

Questionnaire Code./የመጠይቁ ኮድ		Date/ቀን:		Start Time/የተጀመረበት ሰዓት:	
Enumerator's Code/የመረጃ ሰብሳቢው ኮድ					
Woreda Code/የወረዳ ኮድ			Kebele Code/የቀበሌ ኮድ		
Gott Code/የጎጥ ኮድ			House ID/የቤተሰብ ኮድ		
Full Name of Household Head/የቤተሰቡ ሓላፊሙሉ ስም			Sex and AgeofHousehold Head/የቤተሰብ ሓላፊ ፆታ እና እድሜ	M/ወ ☐ F/ሴ ☐ Age/ዕድሜ: /year/አመት	
Full Name of Mother or Caregiver/የእናት ወይም የተንከባካቢ ሙሉ ስም			Sex and Age of Mother or Caregiver/የእናት ወይም የተንከባካቢ ፆታ እና እድሜ	M/ወ ☐ F/ሴ ☐ Age/እድሜ: /year/አመት	

4Household, as the Unit of Survey, refers to "a person or group of persons living together in the same house or compound, sharing the same housekeeping arrangements and being catered for as one unit". (GSS)

Sex and Age of the Youngest Child Under the age of 5/ከአምስት አመት በታች ከሆኑት ልጆች የትንሹ ፆታ እና እድሜ M/ወ ☐ F/ሴ ☐ Age/እድሜ: /month/ወራት	Number of Household Members/የቤተሰብ አባላት ብዛት	Total/ድምር ☐ Female/ሴት: 0~5 years/አመት ☐ 6~15 years/አመት ☐ above 15 years/ ☐ እና ከዚያ በላይ	Male/ወንድ: 0~5 years/አመት ☐ 6~15 years/አመት ☐ above 15 years/ ☐ እና ከዚያ በላይ

① Access to sanitation

1.1 Does your household have a latrine?

ቤተሰቦ መፀዳጃ ቤት አለው?

☐ Yes/አዎ (1) *[move to 1.2]/ወደ ጥያቄ ቁጥር 1.2 ይቀጥሉ*

☐ No/የለውም(2) *[move to 1.20](ወደ ጥያቄ ቁጥር 1.20 ይቀጥሉ)*

1.2 When was your household latrine constructed? (Year in Ethiopian Calander)

ቤተሰቦ ያለው መፀዳጃ የተገነባው መቼ ነበር?

....

1.3 Who influenced you to construct the latrine?

መፀዳጃ ቤትዎን ለመገንባት ያነሳሳዎት ማነው

☐ Government/መንግስት(1)

☐ NGO/መንግስታዊ ያልሆነ ድርጅት(2)

☐ By myself/እኔ እራሴ(3)

☐ Others/ሌላ(Specify)/ይግለፁ (4)____________

1.4	Why did you construct the latrine? መፀዳጃ ቤቱን የገነቡት ለምንድነው? *(check all that apply) /የሚስማሙትን ሁሉ ይምረጡ* *DO NOT SHOW THE OPTIONS!* *ምርጫዎቹን እንዳያሳዩ*	☐ Understanding of its health related importance/ከጤና እና ተያያዥ ጉዳዮች ጋር ያለውን ጥቅም በመረዳት(1) ☐ Social status and dignity/በማህረሰቤ ውስጥ የለኝን ቦታ እና ክብሬን ለማሰጠበቅ(2) ☐ Comfort and convenience/ምቾት (3) ☐ Others/ሌላ(Specify)/ይግለፁ (4)_____________
1.5	Who constructed the latrine? መፀዳጃ ቤቱን የገነባው ማነው? *(check all that apply)/የሚስማሙትን ሁሉ ይምረጡ*	☐ Female Adult/አዋቂ ሴት (1) ☐ Male Adult /አዋቂ ወንድ(2) ☐ Female child /ሴት ልጅ(3) ☐ Male child /ወንድ ልጅ(4) ☐ Others/ሌላ(Specify)/ይግለፁ(5) _____________
	**Note to Enumerator/ማስታወሻ ለ መረጃ ሰብሳቢው* *Child/ልጅ: 0~18/ከ 0-18 አመት ድረሰ* *Adult/አዋቂ: Over 18/ከ18 አመት በላይ*	
1.6	How long did it take for the construction of the latrine? መፀዳጃ ቤቱን ለመገንባት ምን ያህል ጊዜ ፈጀ?	☐ One week/አንድ ሳምንት (1) ☐ Two weeksሁለት ሳምንት(2) ☐ Three weeksሶስት ሳምንት(3) ☐ Four weeksአራት ሳምንት(4) ☐ More than one month /ከ አንድ ወር በላይ (5)
1.7	How deep is the latrine?/የመፀዳጃ ቤቱ ጥልቀት ምን ያክል ነው	……….. Meter/ሜትር
1.8	How much was the cost for the construction of the latrine? መፀዳጃ ቤቱን ለመገንባት ምን ያህል ብር ፈጀ?	……….. Birr /ብር
1.9	Who uses the latrine among your household members? በቤተሰቦ ከሚኖሩት መሀል መፀዳጃ ቤቱን የሚጠቀምበት ማነው?	☐ Female Adult /ሴት አዋቂ(1) ☐ Male Adult /ወንድ አዋቂ(2) ☐ Female Adolescent/ወጣት ሴት (3)

	(check all that apply)የሚስማሙትን ሁሉ ይምረጡ **Note to Enumerator/ማስታወሻ ለ መረጃ ሰብሳቢው* *Under 5 Child/ከአምስት አመት በታች: 0~5/ከ 5 አመት በታች* *Adolescen/ጎረምሳ: 6~18/ከ 6-18 አመት* *Adult/አዋቂ :Over 18/ከ 18 አመት በላይ*	☐ Male Adolescent/ወጣት ወንድ (4) ☐ Female under 5 child/ከ 5 አመት በታች የሆነች ልጅ(5) ☐ Male under 5 child/ከ 5 አመት በታች የሆነ ወንድ ልጅ (6)
1.10	If some household members do not use the latrine, what are the reasons? መፀዳጃ ቤቱን የማይጠቀሙ ሰዎች ካሉ የማይጠቀሙበት ምክንያት ምንድነው? *(check all that apply))የሚስማሙትን ሁሉ ይምረጡ* *DO NOT SHOW THE OPTIONS!* *ምርጫዎቹን እንዳያሳዩ*	☐ Dirty /ቆሻሻ ስለሆነ (1) ☐ Bad odor/መጥፎ ሽታስ ላለው(2) ☐ Wet floor/መሬቱ እርጥ ብስለሆነ(3) ☐ Presence of flies/ዝንቦች ስላሉ (4) ☐ Privacy/የተከለለ ስላልሆነ(5) ☐ Long distance to the latrine/መፀዳጃቤቱ ሩቅ ስለሆነ (6) ☐ Inconvenient road access to the latrine/ወደ ጽንት ቤት መሄጃው መንገዱ ስለማይመች(7) ☐ Others/ሌላ(specify)/ይግለፁ(8)_____________
1.11	If some household members do not use the latrine, where do they go to defecate? መፀዳጃ ቤቱን የማይጠቀሙ የቤተሰብ አባላት የሚፀዳዱት የት ነው? *(check all that apply)የሚስማሙትን ሁሉ ይምረጡ*	☐ Communal latrine /የጋራ መፀዳጃ ቤት(1) ☐ Neighbour's facility/የጎረቤት መፀዳጃ ቤት(2) ☐ Open field/ሜዳ ላይ መፀዳዳት(3) ☐ Dig and bury in the bush/ቆፍረው ከተጠቀሙ በኃላ መቅበር (4) ☐ Others (specify)/ሌላ(ይግለፁ)(5)_____________
1.12	Are you using the latrine during the day time? መፀዳጃ ቤቱን ቀን ቀን ይጠቀሙበታል?	☐ Yes/አዎ(1)*[move to 1.14]]/ወደ ጥያቄ ቁጥር 1.14 ይቀጥሉ* ☐ No/አልጠቀምበትም(2) *[move to 1.13]]/ወደ ጥያቄ ቁጥር 1.13 ይቀጥሉ*

1.13	If the latrine is not used during the day time, most of the time where do you go to defecate? መፀዳጃ ቤቱ በቀን የማይጠቀሙ ከሆነ የቤተሰቡ አባላት ለመፀዳዳት የሚሄዱት ወዴት ነው? *(check only one option)አንድ ምርጫ ብቻ ይምረጡ*	☐ ☐ ☐ ☐ ☐ ☐	Communal latrine /የጋራ መፀዳጃ ቤት(1) Neighbour's facility/የጎረቤት መፀዳጃ ቤት(2) Open field/ሜዳ ላይ መፀዳዳት(3) Dig and bury in the bush/ከተጠቀሙ በኃላ ቆፍረው መቅበር (4) Hold it during the day time/ቀን ቀን አልፀዳዳም (5) Others (specify)/ሌላ(ይግለፁ)(6)________________________
1.14	Are you using the latrine at night? መፀዳጃ ቤቱን ማታ ማታ ይጠቀሙበታል	☐ ☐	*Yes/አዎ(1) [move to 1.16]]/ወደጥያቄቁጥር 1.16ይቀጥሉ* *No/አልጠቀምበትም(2) [move to 1.15]]/ወደጥያቄቁጥር 1.15ይቀጥሉ*
1.15	If the latrine is not used at night, most of the time where do you go to defecate? መፀዳጃ ቤቱ በምሽት ላይ የማይጠቀሙ ከሆነ የቤተሰቡ አባላት ለመፀዳዳት የሚሄዱት ወዴት ነው? *(check only one option)አንድ ምርጫ ብቻ ይምረጡ*	☐ ☐ ☐ ☐ ☐ ☐	Communal latrine /የጋራ መፀዳጃ ቤት(1) Neighbour's facility/የጎረቤት መፀዳጃ ቤት(2) Open field/ሜዳ ላይ መፀዳዳት(3) Dig and bury in the bush/ቆፍረው ከተጠቀሙ በኃላ መቅበር (4) Hold it during night time /ማታ ማታ ከመፀዳዳጽ እቆጠባለሁ (5) Others (specify)/ሌላ(ይግለፁ)(6)________________________
1.16	Is the latrine cleaned or washed regularly? መፀዳጃ ቤቱ በየጊዜው ይፀዳል?	☐ ☐	*Yes/አዎ(1)[move to 1.17]/ወደጥያቄቁጥር 1.17 ይቀጥሉ* *No/አይፀዳም(2) [move to 1.19]]/ወደጥያቄቁጥር 1.19ይቀጥሉ*
1.17	How often is the latrine cleaned/washed? መፀዳጃ ቤቱ በየስንት ጊዜው ይፀዳል? *(check only one option)አንድ ምርጫ ብቻ ይምረጡ*	☐ ☐ ☐ ☐	Daily/በየቀኑ (1) Every other day /በየሁለት ቀኑ (2) Twice a week /በሳምንት ሁለት ጊዜ(3) Once a week/በሳምንት አንድ ጊዜ(4)

☐ Every other week/በሁለት ሳምንት አንድ ጊዜ(5)

☐ Monthly /በየወሩ(6)

1.18	Who cleans/washes the latrine Mostly? በአብዛኛዉ መፀዳጃ ቤቱን የሚያፀዳው ማነው? *(check only one option) አንድ ምርጫ ብቻ ይምረጡ* *(After checking, move to 1.23)ከመረጡ በኋላ ወደ ጥያቄ ቁጥር 1.23 ይቀጥሉ* **Note to Enumerator/ማስታወሻ ለ መረጃ ሰብሳቢው* *Child/ልጅ: 0~18/እስከ 18 አመት ድረስ* *Adultአዋቂ: Over 18/ከ 18 አመት በላይ*	☐ Female Adult / አዋቂ ሴቶች(1) ☐ Male Adult/አዋቂ ወንዶች(2) ☐ Female child/ሴት ልጅ (3) ☐ Male child /ወንድ ልጅ(4)
1.19	Why do you not clean the latrine? መፀዳጃ ቤቱ የማይፀዳው ለምንድነው? *(After writing,move to 1.23)ምክንያቱን ከገለፁ በኋላ ወደ ጥያቄ ቁጥር 1.23 ይቀጥሉ* *(Write all responses, and then probe with 'what else?')ሁሉንም ምላሾች ከፃፉ በኋላ ሌላስ ብለው ይጠይቁ*	i…………………………………… ……………………… ii………………………………………………… ………… iii………………………………………………… ………
1.20	(If No in Q 1.1) Why did you not construct a latrine? (ለ ጥያቄ ቁጥር 1.1 መልሱ የለውም ከሆነ) መፀዳጃ ቤት ለምንአልገነቡም?	☐ Lack of labour/የጉልበት ሠራተኛ ዕጦት (1) ☐ Lack of money for material/የግንባታ እቃዎችን መግዣ ገንዘብ ስለሌለኝ(2) ☐ Lack of techniques and skills for construction of latrine/የመፀዳጃ ቤት ግንባታ ዕውቀትስለሌለኝ(3) ☐ Don't find it necessary/ጥቅም ስለሌለው (4) ☐ Others (specify)/ሌላ(ይግለፁ) (5) ____________

1.21	(If No in Q 1.1) Where do your household members defecate? (ለ ጥያቄ ቁጥር 1.1 መልሱ የለውም ከሆነ) የቤተሰብዎ አባላት የሚፀዳዱት የት ነው? *(check all that apply)የሚስማሙትን ሁሉ ይምረጡ*	☐ Communal latrine /የጋራ መፀዳጃ ቤት(1) ወደ *[move to 1.22B]* ☐ Neighbour's facility/የጎረቤት መፀዳጃ ቤት(2)ወደ *[move to 1.23]* ☐ Open field ሜዳ ላይ መፀዳዳት(3) *[move to 1.22A]* ☐ Dig and bury in the bush /ከተፀዳዱ በኋላ ቆፍረው መቅበር (4) ወደ *[move to 1.22A]* ☐ Others (specify)/ሌላ(ይግለፁ)(5) ____________
1.22A	If you defecate openly, how long does it take to the place for open defecation on average? (back and forth) የሚፀዳዱት ሜዳ ላይ ከሆነ እዛ ለመድረስ ስንትደቂቃ ይፈጅብዎታል ?(ደርሶ ለመመለስ)	( ) minutes/ደቂቃ
1.22B	If you use communal latrine, how long does it take to the communal latrine on average? (back and forth) የሚፀዳዱት የጋራ መፀዳጃ ቦታ ከሆነ እዛ ለመድረስ ስንት ደቂቃ ይፈጅብዎታል?(ደርሶ ለመመለስ)	( ) minutes/ደቂቃ
1.23	Do you have any plan to construct a latrine for your household in the next 12 months? በሚመጡት 12 ወራት ውስጥ የመፀዳጃ ቤት ለመገንባት ዕቅድ አለዎት?	☐ Yes/አዎ(1) *[move to 1.24A]]/ወደጥያቄቁጥር 1.24A ይቀጥሉ* ☐ No/የለኝም(2)*[move to 1.24B] ወደጥያቄቁጥር 1.24B ይቀጥሉ*
1.24A	If yes, explain why? መልሱ አዎ ከሆነ ለምን;ይብራራ? *(Write all responses, and then probe with 'what else?')) ሁሉንም ምላሾች ከፃፉ በኋላ ሌላስ ብለው ይጠይቁ*	i…………………………………………………………… ii……………………………………………………………

		iii…………………………………………………
1.24B	If no, explain why? መልሱ የለኝም ከሆነ ለምን ይብራራ? *(Write all responses, and then probe with 'what else?')) ሁሉንም ምላሾች ከፃፉ በኋላ ሌላስ ብለው ይጠይቁ*	i………………………………………………………… ii……………………………………………………… iii………………………………………………………
1.25	Where do you dispose of faeces of children under 5 years of age? *ከአምስት አመት በታች የሆኑ ልጆችን ዓይነምድር የሚጥሉት የትነው?* *(check only one option) የሚስማሙትንሁሉ ይምረጡ*	☐ Household latrine /በቤተሰቡ መፀዳጃ ቤት(1) ☐ Open field /ሜዳ(2) ☐ Dig hole and bury/ቆፍሮ መቅበር (3) ☐ Solid waste bin/pit /የደረቅ ቆሻሻ መጣያ ቦታ (4) ☐ Others (specify)/ሌላ (ይግለፁ)(5)_____________
1.26	Is there a communal latrine in your community? በሚኖሩበት ማህበረሰብ ውስጥ የጋራ መፀዳጃ ቤት አለ?	☐ Yes /አዎ(1)*[move to 1.27] ወደ ጥያቄ ቁጥር 1.27 ይቀጥሉ* ☐ No (2)/የለም*[move to 2.1]] ወደ ጥያቄ ቁጥር 2.1 ይቀጥሉ*
1.27	Are you satisfied or dissatisfied with the communal latrine? በጋራ መፀዳጃ ቤቱ ደስተኛ ነዎት ወይስ አይደሉም? *(check only one option) አንድ ምርጫ ብቻ ይምረጡ*	☐ *Satisfied (1) ደስተኛ ነኝ [move to 1.29]] ወደ ጥያቄ ቁጥር 1.29 ይቀጥሉ* ☐ *Dissatisfied (2) ደስተኛ አይደለሁም [move to 1.28]] ወደ ጥያቄ ቁጥር 1.28 ይቀጥሉ*
1.28	If dissatisfied, what is the main reason? በጋራ መፀዳጃ ቤቱ ደስተኛ ካልሆኑ ምክንያቱ ምንድነው? *(check all that apply) የሚስማሙትን ሁሉ ይምረጡ*	☐ Dirty/ቆሻሻ ስለሆነ(1) ☐ Smelling/መጥፎ ሽታ ስላለው(2) ☐ Wet floor/የጨቀየ ወለል /መሬቱ ንጹህ ስላልሆነ(3) ☐ Presence of flies/ዝንቦች ስላሉ(4) ☐ No Privacy/የተከለለ ስላልሆነ(5)

☐ Long distance to the latrine /መፀዳጃ ቤቱ ሩቅ ስለሆነ(6)

☐ Others(specify)ሌላ(ይግለፁ)(7)_______________

1.29 Who takes care of the management of the communal latrine?

የየጋራ መፀዳጃቤቱን የሚያስተዳድረው አካል ማነው?

(check all that apply/የሚስማማውን ሁሉ ይምረጡ)

☐ WaSHCO/የውሃ ኮሚቴ(1)

☐ Health Extension Worker/የጤና ባለሙያ(2)

☐ Health Development Army/የጤና ልማት ሰራዊት(3)

☐ Gott Leader/የጎጥ መሪ(4)

☐ Paid labor/ተከፋይ የጉልበት ሰራተኛ(5)

☐ Others(specify)/ሌላ(ይግለፁ)(6)_______________

1.30 Who do you think should manage the communal latrine?

የጋራመፀዳጃ ቤቱን ማስተዳደር የለበት አካልማን ይመስልሃል?

☐ WaSHCO/የውሃ ኮሚቴ(1)

☐ Health Extension Worker/የጤና ባለሙያ(2)

☐ Health Development Army/የጤና ልማት ሰራዊት(3)

☐ Gott Leader/የጎጥ መሪ(4)

☐ Paid labor/ተከፋይ የጉልበት ሰራተኛ(5)

☐ Others(specify)/ሌላ(ይግለፁ)(6)_______________

② Access and Use of Potable Water by Household/በቤተሰቡ የመጠጥ ውሃ ማግኘትና መጠቀም

2.1 What is the main water source for drinking in your household?

በቤትዎ ውስጥ የሚጠጣው ውሃ የሚያገኙት ከየት ነው?

(check only one option)አንድ ምርጫ ብቻ ይምረጡ

☐ Piped individual yard connection-own /በግቢዬ ውስጥ የተዘረጋ የግል ቧንቧ ውሃ ቧንቧ ውሃ (1)

☐ Piped connection Neighbour's/የጎረቤት ቧንቧ ውሃ (2)

☐ Communal Water point/የጋራ ውሃ መቅጃ ቦኖ ውሃ (3)

☐ Protected Shallow well with hand pump (4)

☐ Hand dug well with hand pump/ፓምፕ ያለው በእጅ የተቆፈረ የውሃ ጉድጓድ (5)

		☐ Unprotected hand dug well/ያልተጠበቀ በእጅ የተቆፈረ የውሃ ጉድጓድ (6)
		☐ Unprotected spring/ያልተጠበቀ ምንጭ (7)
		☐ Protected spring/የተጠበቀ ምንጭ (8)
		☐ River/Stream/ወንዝ (9)
		☐ Pond or basin water/ኩሬ (10)
		☐ Rain harvested waterየታቆረ የዝናብ ውሃ (11)
		☐ Other (specify)ሌላ (ይግለፁ) (12) ____________________
2.2	What is the main water source for bathing in your household? በቤትዎ ውስጥ የገላ ንፅህናን ለመጠበቅ የሚጠቀሙት ውሃ የሚያገኙት ከየት ነው “? *(check only one option) አንድ ምርጫ ብቻ ይምረጡ*	☐ Piped individual yard connection-own /በግቢዮ ውስጥ የተዘረጋ የግል ቧንቧ ውሃ ቧንቧ ውሃ (1) ☐ Piped connection Neighbour's/የጎረቤት ቧንቧ ውሃ (2) ☐ Communal Water point/የጋራ ውሃ መቅጃ ቦኖ ውሃ (3) ☐ Protected Shallow well with hand pump (4) ☐ Hand dug well with hand pump/ፓምፕ ያለው በእጅ የተቆፈረ የውሃ ጉድጓድ (5) ☐ Unprotected hand dug well/ያልተጠበቀ በእጅ የተቆፈረ የውሃ ጉድጓድ (6) ☐ Unprotected spring/ያልተጠበቀ ምንጭ (7) ☐ Protected spring/የተጠበቀ ምንጭ (8) ☐ River/Stream/ወንዝ (9) ☐ Pond or basin water/ኩሬ (10) ☐ Rain harvested waterየታቆረ የዝናብ ውሃ (11) ☐ Other (specify)ሌላ (ይግለፁ) (12) ____________________
2.3	What is the main water source for cooking in your household? በቤትዎ ውስጥ ምግብ ለማብሰል የሚጠቀሙት ውሃ የሚያገኙት ከየት ነው ?	☐ Piped individual yard connection-own /በግቢዮ ውስጥ የተዘረጋ የግል ቧንቧ ውሃ ቧንቧ ውሃ (1) ☐ Piped connection Neighbour's/የጎረቤት ቧንቧ ውሃ (2) ☐ Communal Water point/የጋራ ውሃ መቅጃ ቦኖ ውሃ (3) ☐ Protected Shallow well with hand pump (4) ☐ Hand dug well with hand pump/ፓምፕ ያለው በእጅ የተቆፈረ የውሃ ጉድጓድ (5)

	(check only one option) አንድ ምርጫ ብቻ ይምረጡ	☐	Unprotected hand dug well/ያልተጠበቀ በእጅ የተቆፈረ የውሃ ጉድጓድ (6)
		☐	Unprotected spring/ያልተጠበቀ ምንጭ (7)
		☐	Protected spring/የተጠበቀ ምንጭ (8)
		☐	River/Stream/ወንዝ (9)
		☐	Pond or basin water/ኩሬ (10)
		☐	Rain harvested waterየታቆረ የዝናብ ውሃ (11)
		☐	Other (specify)ሌላ (ይግለፁ) (12) ____________________
2.4	What is the main water source for watering animal in your household? ለእንስሳት መጥጥ የሚጠቀሙት ውሃ የሚያገኙት ከየት ነው ?	☐	Piped individual yard connection-own /በግቢዬ ውስጥ የተዘረጋ የግል ቧንቧ ውሃ ቧንቧ ውሃ (1)
		☐	Piped connection Neighbour's/የጎረቤት ቧንቧ ውሃ (2)
		☐	Communal Water point/የጋራ ውሃ መቅጃ ቦኖ ውሃ (3)
		☐	Protected Shallow well with hand pump (4)
	(check only one option) አንድ ምርጫ ብቻ ይምረጡ	☐	Hand dug well with hand pump/ፓምፕ ያለው በእጅ የተቆፈረ የውሃ ጉድጓድ (5)
		☐	Unprotected hand dug well/ያልተጠበቀ በእጅ የተቆፈረ የውሃ ጉድጓድ (6)
		☐	Unprotected spring/ያልተጠበቀ ምንጭ (7)
		☐	Protected spring/የተጠበቀ ምንጭ (8)
		☐	River/Stream/ወንዝ (9)
		☐	Pond or basin water/ኩሬ (10)
		☐	Rain harvested waterየታቆረ የዝናብ ውሃ (11)
		☐	Other (specify)ሌላ (ይግለፁ) (12) ____________________
2.5	What is the main water source for washing clothes in your household? የልብስ ንፅህና ለመጠበቅ የሚጠቀሙት ውሃ የሚያገኙት ከየት ነው?	☐	Piped individual yard connection-own /በግቢዬ ውስጥ የተዘረጋ የግል ቧንቧ ውሃ ቧንቧ ውሃ (1)
		☐	Piped connection Neighbour's/የጎረቤት ቧንቧ ውሃ (2)
		☐	Communal Water point/የጋራ ውሃ መቅጃ ቦኖ ውሃ (3)
		☐	Protected Shallow well with hand pump (4)
		☐	Hand dug well with hand pump/ፓምፕ ያለው በእጅ የተቆፈረ የውሃ ጉድጓድ (5)

	(check only one option) አንድ ምርጫ ብቻ ይምረጡ	☐ Unprotected hand dug well/ያልተጠበቀ በእጅ የተቆፈረ የውሃ ጉድጓድ (6) ☐ Unprotected spring/ያልተጠበቀ ምንጭ (7) ☐ Protected spring/የተጠበቀ ምንጭ (8) ☐ River/Stream/ወንዝ (9) ☐ Pond or basin water/ኩሬ (10) ☐ Rain harvested waterየታቆረ የዝናብ ውሃ (11) ☐ Other (specify)ሌላ (ይግለፁ) (12) ____________________
2.6	Are you able to access water from any of the above mentioned sources everyday all year round? ከላይ ከተዘረዘሩት ከማንኛውም የውሃ ማግኛ መንገዶች መሀል አመቱን ሙሉ በየቀኑ ውሃ ያገኛሉ?	☐ Yes/አዎ (1) *[move to 2.7] ወደ ጥያቄ ቁጥር 2.7ይቀጥሉ* ☐ No /አላገኝም(2) *[move to 2.8]]ወደ ጥያቄ ቁጥር 2.8ይቀጥሉ*
2.7	If yes, please indicate those that provide water everyday all year round. *መልሱ አዎ ከሆነ ከየትኞቹ የውሃ ማግኛ መንገዶች አመቱን ሙሉ በየቀኑ ውሃ እንደሚያገኙ ይግለፁ?* *(check all that apply/የሚስማማውን ሁሉ ይምረጡ)*	☐ Piped individual yard connection-own /በግቢዬ ውስጥ የተዘረጋ የግል ቧንቧ ውሃ ቧንቧ ውሃ (1) ☐ Piped connection Neighbour's/የጎረቤት ቧንቧ ውሃ (2) ☐ Communal Water point/የጋራ ውሃ መቅጃ ቦኖ ውሃ (3) ☐ Protected Shallow well with hand pump (4) ☐ Hand dug well with hand pump/ፓምፕ ያለው በእጅ የተቆፈረ የውሃ ጉድጓድ (5) ☐ Unprotected hand dug well/ያልተጠበቀ በእጅ የተቆፈረ የውሃ ጉድጓድ (6) ☐ Unprotected spring/ያልተጠበቀ ምንጭ (7) ☐ Protected spring/የተጠበቀ ምንጭ (8) ☐ River/Stream/ወንዝ (9) ☐ Pond or basin water/ኩሬ (10) ☐ Rain harvested waterየታቆረ የዝናብ ውሃ (11) ☐ Other (specify)ሌላ (ይግለፁ) (12) ____________________
	If sources are outside house, how much time	

2.8	***(minutes)*** does it take, on average, to go to water source, get water and come home? ውሃውን የሚያገኙት ከቤት ውጭ ከሆነ ውሃውን የሚያገኙበት ቦታ ደርሶ ለመመለስ ምን ያህል ጊዜ ይፈጅብዎታል?	☐ Less than 15 minutes/ከ15 ደቂቃ በታች (1) ☐ 15 to 30 minutes/ከ15-30 ደቂቃ(2) ☐ 30 to 60 minutes/ከ30-60 ደቂቃ(3) ☐ 60 to 120 minutes/ከ 60-120 ደቂቃ(4) ☐ More than 120 minutes/ከ120 ደቂቃ በላይ (5)
2.9	Who is mainly responsible for fetching water in the household? ከቤተሰቡ አባላት መሀል ውሃ የሚቀዳው ማነው? **Note to Enumerator/ማስታወሻ ለ መረጃ ሰብሳቢው* *Child/ልጅ: 0~18/ከ 18 አመት በታች* *Adult/አዋቂ: Over 18/ከ 18 አመት በላይ* *(check only one option) አንድ ምርጫ ብቻ ይምረጡ*	☐ Male adult/ ወንድ አዋቂ (1) ☐ Female adult/ሴት አዋቂ(2) ☐ Male child/ወንድ ልጅ(3) ☐ Female child/ሴት ልጅ(4)
2.10	Which of the sources do you depend on **most** for your water supply needs? ከተዘረዘሩት ከማንኛውም የውሃ ማግኛ መንገዶች መሀል የትኛውን ነው በአብዛኛው የሚያገኙት? *(check only one option) አንድ ምርጫ ብቻ ይምረጡ*	☐ Piped individual yard connection-own /በግቢዬ ውስጥ የተዘረጋ የግል ቧንቧ ውሃ ቧንቧ ውሃ (1) ☐ Piped connection Neighbour's/የጎረቤት ቧንቧ ውሃ (2) ☐ Communal Water point/የጋራ ውሃ መቅጃ ቦኖ ውሃ (3) ☐ Protected Shallow well with hand pump (4) ☐ Hand dug well with hand pump/ፓምፕ ያለው በእጅ የተቆፈረ የውሃ ጉድጓድ (5) ☐ Unprotected hand dug well/ያልተጠበቀ በእጅ የተቆፈረ የውሃ ጉድጓድ (6) ☐ Unprotected spring/ያልተጠበቀ ምንጭ (7) ☐ Protected spring/የተጠበቀ ምንጭ (8)

		☐ River/Stream/ወንዝ (9) ☐ Pond or basin water/ኩሬ (10) ☐ Rain harvested waterየታቆረ የዝናብ ውሃ (11) ☐ Other (specify)ሌላ (ይግለፁ) (12) ____________________
2.11	Is the **main water source** used for any other purposes aside from household use? በአብዛኛው የሚያገኙትን ውሃ ከቤት ውጭ ላለዉ ለሌላ ነገር ይጠቀሙበታል? (e.g. agriculture, agro-processing, income generation, etc.) (ለምሳሌ፡ግብርና፣የግብርና ውጤቶችን ማቀነባበር፣እንደ ገቢ ምንጭ)	☐ Yes/አዎ (1) ☐ *No/አልጠቀምም (2) [move to 2.13] ወደ ጥያቄ ቁጥር 2.13 ይቀጥሉ*
2.12	If yes, what other purposes is it used for? *(check all that apply/የሚስማማውን ሁሉ ይምረጡ)*	☐ Crop Farming/ለሰብል ምርት(1) ☐ Livestock /ከብቶች (2) ☐ Agro-processing/የግብርና ውጤቶችን ለማቀነባበር (3) ☐ income from water sale/ከውሃ ሽያጭ የሚገኝ ገቢ (4) ☐ Other non-agro Income Generation/ሌላ ከግብርና ውጪ (5)
2.13	How often does your household fetch water? ውሃው የሚቀዳው በ ስንት ጊዜ ነው?	☐ More than twice a day/በቀን ከ ሁለት ጊዜ በላይ (1) ☐ Once a day/በቀን አንዴ(2) ☐ Once in every other day/በሁለት ቀን አንዴ (3) ☐ Once in more than three days/ከ ሶስት ቀን በላይ በሆነ ጊዜ ውስጥ አንድ ጊዜ(4)
2.14	What types of containers do you use to fetch water? ውሃ ለመቅዳት የምትጠቀሙበት ዕቃ ምን አይነት ነው.	☐ 5 Liter jerry can/5 ሊትር ጀሪካን (1) ☐ 10 Liter jerry can/10ሊትር ጀሪካን(2) ☐ 20 Liter jerry can/20ሊትር ጀሪካን (3) ☐ 25 Liter jerry can/25ሊትር ጀሪካን (4) ☐ 30 Liter jerry can/30ሊትር ጀሪካን (5)

	(check all that apply)/የሚስማሙትን ሁሉ ይምረጡ	☐ Others/ሌላ(Specify Liter)/በ ሊትር መጥነው ይግለፁ(6)_____________
2.15	How many containers per day do your household fetch? ለቤትዎ ምን ያክል ውሃ ይቀዳል በቀን *(check all that apply)/የሚስማሙትን ሁሉ ይምረጡ*	………..5 Liter jerry can/5 ሊትር ጀሪካኖች (1) ………..10 Liter jerry can/10 ሊትር ጀሪካኖች(2) ………..20 Liter jerry can/20 ሊትር ጀሪካኖች((3) ………..25 Liter jerry can/25ሊትር ጀሪካኖች((4) ………..30 Liter jerry can/30ሊትር ጀሪካኖች((5) ………..Others (6)(ሌላ)
2.16	Do you pay a tariff for water? ለውሃ ታሪፍ ይከፍላሉ?	☐ Yes /አዎ(1) ☐ No/አልከፍልም(2) *[move to 2.24]ወደ ጥያቄ ቁጥር 2.24 ይቀጥሉ*
2.17	What is the mode of payment? የውሃ ዋጋ አከፋፈል ሁኔታ እንዴት ነው? *(check only one option) አንድ ምርጫ ብቻ ይምረጡ*	☐ Cash/በጥሬ ገንዘብ(1) ☐ In kind /በአይነት(2)
2.18	If yes, how do you pay? መልሱ አዎ ከሆነ የአከፋፈሉ ሁኔታ እንዴት እንደሆነ ይግለፁ? *(check only one option) አንድ ምርጫ ብቻ ይምረጡ*	☐ Every time of fetching water/ውሃ ስቀዳ(1) ☐ Daily/በየቀኑ (2) ☐ Weekly/በየሳምንቱ(3) ☐ Monthly/በየወሩ(4) ☐ Seasonally-3months range/በየተወሰነ ጊዜ(በ ሶስት ወር ጊዜ ውስጥ አንዴ)(5) ☐ Seasonally -6months range/በየተወሰነ ጊዜ(ስድስት ወር)(6) ☐ Yearly/በየአመቱ (7)

		☐ others (specify)/ሌላ (ይግለፁ)________________________
2.19	How much do you pay? የሚከፍሉት ስንት ነው?	……….. Every time of fetching water/ውሃ ስቀዳ(1) (Assuming 20liter Jerry can) ……….. Daily/በየቀኑ (2) ……….. Weekly/በየሳምንቱ(3) ……….. Monthly/በየወሩ(4) ……….. Seasonally-3months range/በየተወሰነ ጊዜ(በ ሶስት ወር ጊዜ ውስጥ አንዴ)(5) ……….. Seasonally -6months range/በየተወሰነ ጊዜ(ስድስት ወር)(6) ……….. Yearly/በየአመቱ (7) ……….. others (8)
2.20	Is the current amount affordable? የወቅቱ ውሃ ዋጋ ለከፍሉት የሚችሉትና አቅሞን ያገናዘበ ነው?	☐ Yes/አዎ (1) *[move to 2.22]ወደ ጥያቄ ቁጥር 2.21ይቀጥሉ* ☐ No/አልችለውም(2) *[move to 2.21]ወደ ጥያቄ ቁጥር 2.21ይቀጥሉ*
2.21	How much can you afford? በአቅሞ ልክ መከፈል የሚችሉት ስንት ነው?	……….. Every time of fetching water/ውሃ ስቀዳ(1) (Assuming 20liter Jerry can) ……….. Daily/በየቀኑ (2) ……….. Weekly/በየሳምንቱ(3) ……….. Monthly/በየወሩ(4) ……….. Seasonally-3months range/በየተወሰነ ጊዜ(በ ሶስት ወር ጊዜ ውስጥ አንዴ)(5) ……….. Seasonally -6months range/በየተወሰነ ጊዜ(ስድስት ወር)(6) ……….. Yearly/በየአመቱ (7) ……….. others (8)
2.22	Who mainly sets the tariff amount?	☐ Water committee/የውሃ ኮሚቴ(1) ☐ Gott Leader/የጎጥ መሪ(2) ☐ Kebele WASH Committee/የቀበሌ የውሃ፣ የአካባቢ እና የግል ንጽህና ኮሚቴ (3)

	የሚከፈለው የውሃ ዋጋ ተምን በገንዘብ ምን ያህል መሆን እንዳለበት የሚወስነው ማነው? *(check only one option)*	☐ Woreda WASH Team/ የወረዳው የውሃ፣ የአካባቢ እና የግል ንጽህና ኮሚቴ(4) ☐ Community Leaders /የመንደር መሪዎች(5) ☐ Personal Operator /ውሃ የሚያከፋፍለው ሰው (6) ☐ Others (999)ሌላ (specify)/___________________________
2.23	Were you consulted when the tariff amount was being set? የየውሃ ዋጋ ተመን ምን ያህል መሆን እንዳለበት ሲወሰን ሀሳብዎን ተጠይቀው ነበር? *(After writing,move to 2.25)ከፃፉ በኋላ ወደ ጥያቄ ቁጥር2.25ይቀጥሉ*	☐ Yes/አዎ (1) ☐ No/አልተጠየኩም(2)
2.24	(If No in Q2.16) If you don't pay tariff for water, why? (ለ ጥያቄ ቁጥር 2.16 መልሱ አልከፍልም ከሆነ)፣ታሪፍ የማይከፍሉት ለምንድነው? *(check only one option)አንድ ምርጫ ብቻ ይምረጡ*	☐ Because I Pay Per breakdown /ሲሰበር ለጥገና ስለምከፍል(1) ☐ I receive free water in exchange for service/ህብረተሰቡን ስለማገለግል በልዋጭ ውሃ በነፃ እንደጠቀም ስለተፈቀደልኝ(2) ☐ I pay through communal fundraising/በህዝብ መዋጮ ስለከፈልኩ (3) ☐ Exempted (Too poor/Old)/አቅመደካማ/ድሃ ስለሆንኩ /(4) ☐ Source is from river/stream/dugout /ውሃው የሚገኘው ከ ወንዝ፣ከ ምንጭ ወይም ከ ጉድጓድ ስለሆነ (5) ☐ Other (specify)/ሌላ(ይገለፅ)(6) _________________________
2.25	Who is responsible for operation and maintenance of the water supply in your vicinity? በአካባቢዎ የውሃ አቅርቦትን መከታተል፣ መስራትና መጠገን የሚመለከተዉ ማንን ነው	☐ Water committee/የውሃ ኮሚቴ(1) ☐ Gott Leader/የጎጥ መሪ(2) ☐ Kebele WASH Committee/የቀበሌ ውሃ ኮሚቴ (3) ☐ Woreda WASH Team /የወረዳ ውሃ ኮሚቴ(4) ☐ Community Leaders /የመንደር መሪዎች(5)

☐ Personal Operator/ውሃ የሚያከፋፍለው ሰው (6)

☐ Others (999)ሌላ (specify)/(7)______________________

2.26	When there is a problem with your main source of water, who do you tell or ask for help? በአካባቢዎ በውሃ አቅርቦት ላይ ችግር ሲኖር የምትናገሩት ወይም እርዳታ የምትጠይቁት ማንን ነው?	☐ Water committee/የውሃ ኮሚቴ(1) ☐ Gott Leader/የጎጥ መሪ(2) ☐ Kebele WASH Committee/የቀበሌ የውሃ፣ የአካባቢ እና የግል ንጽህናኮሚቴ(3) ☐ Woreda WASH Team /የወረዳው የውሃ፣ የአካባቢ እና የግል ንጽህናኮሚቴ(4) ☐ Community Leaders /የመንደር መሪዎች(5) ☐ Personal Operator/ውሃ የሚያከፋፍለው ሰው (6) ☐ Others (999)ሌላ/ 7)______________________

③ **Hygiene and Health/የግል ንፅህና እና ጤና**

3.1	Do you store drinking water separately at your household? የሚጠጡትን ውሃ የሚስቀምጡት ከሌላ ውሃ ለይተው ነው?	☐ Yes/አዎ (1) *[move to 3.2] ወደ ጥያቄ ቁጥር 3.2 ይቀጥሉ* ☐ No/አይደለም(2)*[move to 3.5] ወደ ጥያቄ ቁጥር 3.5ይቀጥሉ*
3.2	If yes, in what type of container(s) do you store drinking water(mostly)? መልሱ አዎ ከሆነ ውሃውን በአብዛኛዉ የሚያስቀምጡት ምን አይነት ዕቃ ውስጥ ነው? *(check only one option)አንድ ምርጫ ብቻ ይምረጡ*	☐ Storage Tank/የውሃ ማጠራቀሚያ (1) ☐ Barrel/በርሜል(2) ☐ Basin/ሳፋ(3) ☐ Bucke/ባልዲ (4) ☐ Jerrycans/ጀሪካን(5) ☐ Jars /በእንስራ(6) ☐ Other (Specify)/ሌላ (ይግለፁ) (7) ____________

3.3 If containers are full, how long willwater last (in days)?

የየውሃ ማጠራቀሚያ እቃዎ ተሞልቶሲያበቃ፣ተጠቅመውበት ሚያልቀው በምን ያህል ጊዜ ነው?

……….*Days/ቀናት*

3.4 How often do you clean the containers?

የውሃ እቃዎቹ በየስንት ጊዜ ይታጠባሉ?

(check only one option)*አንድ ምርጫ ብቻ ይምረጡ*

- ☐ Daily/በየቀኑ (1)
- ☐ Multiple times in a week/በሳምንት ውስጥ የተወሰነ ጊዜ (2)
- ☐ Weekly/በየሳምንቱ (3)
- ☐ Twice a month/በየሁለት ሳምንቱ(4)
- ☐ Monthly/በየወሩ(5)
- ☐ Seasonally/በየ 6 ወሩ (6)
- ☐ Yearly በየዓመቱ(7)
- ☐ Never /አይታጠቡም(8)

3.5 Do you do anything to the water to make it safer for drinking?

የሚጠጡትን ውሃ ንጽህናው የተጠበቀ እንዲሆን ላማድረግ የሚያደርጉት ነገር አለ?

- ☐ Yesአዎ(1)*[move to 3.6] ወደ ጥያቄ ቁጥር 3.6 ይቀጥሉ*
- ☐ No/የለም(2) *[move to 3.9] ወደ ጥያቄ ቁጥር 3.9ይቀጥሉ*

3.6 If yes, what do you do?

መልሱ አዎ ከሆነ ፣የሚያደርጉት ምንድነው?

(check all that apply)/የሚስማሙትን ሁሉ ይምረጡ

- ☐ Boil/ማፍላት (1)
- ☐ Add Weha Agar /ውሃ አጋር መጨመር (2)
- ☐ Strain it through a cloth/በልብስ ማጥለል(3)
- ☐ water filter (ceramic, sand, composite, etc.)/በአሸዋ እና በመሳሰሉት ማጣራት (4)
- ☐ Solar disinfection/በፀሀይ ተውሳትን መግደል (5)
- ☐ Let it stand and settle/በራሱ እንዲጠል መተው (6)
- ☐ Others (specify)/ሌላ(ይገለፅ)(7) ____________

3.7	How often do you treat the drinking water?	☐ daily/ብር በቀን ☐ multiple times a week/ ☐ weekly/ብር በ ወር ☐ Twice a month Monthly
3.7-1	How much does it cost you to treat the water? የየመጠጥ ውሃው ንጽህናው የተጠበቀ እንዲሆን ለማከም በወር ስንት ብር ያወጣሉ	……….. daily/ብር በቀን ……….. multiple times a week/ ……….. weekly/ብር በ ወር ……….. Twice a month ……….. Monthly
3.8	Why do you treat the water? የመጠጥ ውሃው ማከምና ንጽኅናው የተጠበቀእንዲሆን ማድረጉ ለምን አስፈለገ *(check all that apply)/የሚስማሙትን ሁሉ ይምረጡ*	☐ Known bad quality/ውሃው ጥራት ስለሌለው(1) ☐ Perceived bad quality/ውሃው ጥራት የለውም ተብሎ ስለሚታመን (2) ☐ Government procedure/የመንግስት አሰራር ሂደት(3) ☐ Other (specify)/ሌላ(ይገለፅ) _____________ (4)
3.9	Do you know the critical times for hand washing? እጅዎን መታጠብ ያለብዎት ወሳኝ ጊዜዎች /አጋጣሚዎች መቼ መቼ እንደሆነ ያውቃሉ	☐ Yes/አዎ (1) *[move to 3.10] ወደ ጥያቄ ቁጥር 3.10 ይቀጥሉ* ☐ No/አላውቅም (2) *[move to 3.11] ወደ ጥያቄ ቁጥር 3.11ይቀጥሉ*
3.10	If yes, what are these critical times for hand washing? መልሱ አዎ ከሆነ መቼ መቼ እንደሆነ ይንገሩኝ *(check all that apply)/የሚስማሙትን ሁሉ ይምረጡ*	☐ Before eating/ከምግብ በፊት(1) ☐ After defecation/ሽንት ከተፀዳዱ በኋላ(2) ☐ Before food preparation/ምግብ ከማዘጋጀት በፊት(3) ☐ After cleaning a child's buttocks, after defication /የተጸዳዳን ሕፃን ልጅ መቀመጫውን አጣጥበው ሲያበቁ(4) ☐ Before feeding a child/ህፃን ልጅን ከመመገብ በፊት(5)

☐

	DO NOT SHOW THE OPTIONS!ምርጫዎቹን እንዳያሳዩ!	☐ After handling a sick person/የታመመ ሰውን አስተናግደው ሲጨርሱ(6) ☐ When you return from a social events (e.g funeral) ከማህበራዊ ጉዳዮች ሲመለሱ(ምሳሌ፡ቀብር)(7) ☐ Others(Specify)ሌላ(ይግለፁ)(8)________________
3.11	When do you usually practise hand washing? እጅዎን የሚታጠቡት መቼ መቼ ነው *(check all that apply)/የሚስማሙትን ሁሉ ይምረጡ* *DO NOT SHOW THE OPTIONS!ምርጫዎቹን እንዳያሳዩ!*	☐ Before eating/ከምግብ በፊት(1) ☐ After defecation/ከተፀዳዱ በኋላ(2) ☐ Before food preparation/ምግብ ከማዘጋጀት በፊት(3) ☐ After cleaning a child's buttocks/የሕፃን ልጅን መቀመጫ አጣጥበው ሲጨርሱ(4) ☐ Before feeding a child/ህፃን ልጅን ከመመገብ በፊት(5) ☐ After handling a sick person/የታመመ ሰውን አስተናግደው ሲጨርሱ(6) ☐ When you return from a social events (e.g funeral)ከማህበራዊ ጉዳዮች ሲመለሱ(ምሳሌ፡ቀብር)(7) ☐ Others (Specify)ሌላ(ይግለፁ)(8)__________________
3.12	Do you remember practising hand washing yesterday? ትላንት እጅዎን ታጥበዋል	☐ Yes/አዎ *[move to 3.13] ወደ ጥያቄ ቁጥር 3.13 ይቀጥሉ* ☐ No/አልታጠብኩም *[move to 3.18]] ወደ ጥያቄ ቁጥር 3.18 ይቀጥሉ*
3.13	If yes, when did you practise hand washing yesterday? መልሱ አዎ ከሆነ ትላንት እጅዎን የታጠቡት ምን ካደረጉ በኋላ ነው *(check all that apply))* *የሚስማሙትንሁሉንይምረጡ*	☐ Before eating/ከምግብ በፊት(1) ☐ After defecation/ከተፀዳዱ በኋላ(2) ☐ Before food preparation/ምግብ ከማዘጋጀት በፊት(3) ☐ After cleaning a child's buttocks/የተጸዳዳን ሕፃን ልጅ መቀመጫውን አጣጥበው ሲያበቁ(4) ☐ Before feeding a child/ህፃን ልጅን ከመመገብ በፊት(5) ☐ After handling a sick person/የታመመ ሰውን አስተናግደው ሲጨርሱ(6)

	DO NOT SHOW THE OPTIONS!ምርጫዎቹንእንዳያሳዩ!	☐ When you return from a social events (e.g funeral)ከማህበራዊ ጉዳዮች ሲመለሱ(ምሳሌ፡ቀብር)(7) ☐ Others (Specify)ሌላ(ይግለፁ)(8)________________
3.14	Why did you practise hand washing on the occasionsyou mentioned above? ከላይ የተጠቀሱትን ነገሮች ካደረጉ በኋላ እጅዎን የታጠቡት ለምንድነው *(check all that apply)) የሚስማሙትንሁሉይምረጡ* *DO NOT SHOW THE OPTIONS!ምርጫዎቹንእንዳያሳዩ!*	☐ To prevent disease/በሽታን ለመከላከል (1) ☐ To remove dirt/ቆሻሻን ለማስለቀቅ(2) ☐ Told by Health Professionals/የጤና ባለሙያዎች ስለነገሩኝ(3) ☐ Learnt from family members/የቤተሰቤ አባላት ግንዛቤ ሰተውኝ (4) ☐ Ohters/ሌላ(Specify)/ይግለፁ(5) ________________
3.15	Aside from water, Did you use anything to wash your hands yesterday? ትላንት እጅዎን ሲታጠቡ ከውሃ ሌላ የተጠቀሙት ነገር አለ	☐ Yes/አዎ (1)*[move to 3.16] ወደ ጥያቄ ቁጥር 3.17ይቀጥሉ* ☐ No/የለም(2)*[move to 3.17] ወደ ጥያቄ ቁጥር 3.17 ይቀጥሉ*
3.16	If yes, what did you use? መልሱ አዎ ከሆነ የተጠቀሙት ምንድነው *[move to 3.18 after checking one option]/አንድ ምርጫ ከመረጡ በኋላ ወደ ጥያቄ ቁጥር 3.18 ይቀጥሉ*	☐ Soap/ሳሙና (1) ☐ Ash/አመድ(2) ☐ Others/ሌላ(Specify) ይግለፁ (3) ________________
3.17	If you didn't use soap or any other alternative, why not? ሳሙና ወይም ሌላ አማራጭ ካልተጠከሙ ለምን	☐ not affordable /የመግዛትአቅም የለኝም (1) ☐ not accessibleማግኘት አልችልም(2) ☐ not important/ጥቅም ያለው አይመስለኝም(3) ☐ Other(specify)/ሌላ (ይግለፁ) (4) ______________
3.18	Do you have a specific hand washing facility? ለእጅ መታጠቢያ ብቻ የተዘጋጀ ቦታ አለዎት	☐ Yes/አዎ (1) ☐ No/የለኝም(2) *[move to 3.20] ወደ ጥያቄ ቁጥር 3.20ይቀጥሉ*

3.19	If yes, what facility do you use for hand washing? ለእጅ መታጠቢያ ብቻ የተዘጋጀ ቦታ ካለዎት ምን እንደሆነ ይግለፁ *(check only one option)አንድ ምርጫ ብቻ ይምረጡ*	☐ Jerrycans with tap /ቧንቧ የተገጠመበት ጀሪካን (1) ☐ Jerrycans with plug/ውታፍ የተገጠመበት ጀሪካን (2) ☐ Tippy Tap/ከቧንቧ (3) ☐ Other (specify) ሌላ(ይግለፁ) (4) _____________	
3.20	What is your major source of information about health and hygiene? ስለ ግል ንፅህና እና የጤና መረጃበዋናነት የሚያገኙት ከየት ነው *(check all that apply)) የሚስማሙትንሁሉይምረጡ*	☐ Government Health Professionals (HEW/HC)/የመንግስት የጤና ባለሙዎች (1) ☐ Neighbor/ጎረቤት(2) ☐ Family member/የቤተሰብ አባል(3) ☐ Media /የዜና እና መረጃ ማሰራጫዎች(4) ☐ School/ትምህርትቤት(5) ☐ NGO/መንግስታዊ ያልሆኑ ድርጅቶች(6) ☐ Religious leader/የሀይማኖት መሪ(7) ☐ Other/ሌላ(specify)/ይግለፁ(8) _____________	
3.21	Do you know of any WASH related diseases? ከአካባቢ እና የግል ንፅህናጉድለት ጋር ተያያዠ በሽታዎችን ያውቃሉ	☐ Yes /አዎ(1) ☐ No/አላውቅም(2)	*[move to 3.23] ወደ ጥያቄ ቁጥር 3.23 ይቀጥሉ*
3.22	If yes, name those you know. መልሱ አዎ ከሆነ የሚያውቋቸውን ይዘርዝሩ *(check all that apply)) የሚስማሙትንሁሉይምረጡ*	☐ Diarrhoea/ተቅማጥ(1) ☐ Bilhazia/ብልሀርዝያ(2) ☐ Guinea Worm/የጊኒ ትል(3) ☐ Typhoid/ታይፎይድ(4) ☐ Trachoma/ትራኮማ(5) ☐ Cholera/ኮሌራ(6) ☐ Malaria/ወባ(7)	

	*DO NOT SHOW THE OPTIONS!*ምርጫዎቹንእንዳያሳዩ!	☐ Intestinal Worms/የአንጀት ትል(8) ☐ Other (Specify)ሌላ (ይግለፁ (9) ______________
3.23	Has the **Youngestchild**under five (5) years in your household experienced diarrhoea (3 or more watery stools in a 24 hour period) in the past 7 days? ከ5 አመት በታች ካሉት ሕፃን ልጆች ትንሹ ባለፉት 7 ቀናት ውስጥ ውስጥ ተቅማጥ(በ 24 ሰዓት ውስጥ 3 ጊዜ እና ከዚያ በላይ ውሃማ ዓይነምድር)ይዞት ነበር	☐ Yes/አዎ (1) ☐ No/የለም(2)
3.24	On the average how often does the youngest child get diarrhoea? በአማካኝ ሕፃኑ ልጅ በየስንት ጊዜ ተቅማጥ ይይዘዋል *(check only one option)አንድ ምርጫ ብቻ ይምረጡ*	☐ Once a month/በወር አንዴ(1) ☐ Quarterly (2) ☐ Once half-yearly/በ6ወር አንዴ(3) ☐ Once yearly/በአመት አንዴ(4) ☐ Once every two year/በሁለት አመት አንዴ(5) ☐ Once in over two years/ከሁለት አመት በላይ በሆነ ጊዜ አንዴ((6) ☐ Others ሌላ (ይግለፁ) (7)______________
3.25	On the average how many days is the youngest child sick per each episode of diarrhoea?በአማካኝ ሕፃኑ ልጅ ተቅማጥ ይዞት ለምን ያህል ጊዜ ይቆይበታል	( ) days
3.26	How many among your household members have contracted diarrhoea (3 or more watery stools in a 24 hour period) in the past 7 days?	Female/ሴት: 0~5 year/አመት ☐ Male/ወንድ: 0~5 year/አመት ☐

	ባለፉት 7 ቀናት ውስጥ ከቤተሰብዎ አባላት መሀል ተቅማጥ(በ 24 ሰዓት ውስጥ 3 ጊዜ እና ከዚያ በላይ ውሃማ ዓይነምድር)የያዘው ሰው አለ	6~15 year/አመት ☐ 6~15 year/አመት ☐ above 15/ከ15 አመት በላይ ☐ above 15/ከ15 አመት በላይ ☐
3.27	Normally, do you treat the child with diarrhoea? ሕፃኑ ልጅ ተቅማጥ በያዘው ጊዜ ሁሉ የስታምሙታል	☐ Yes (1)*[move to 3.28] ወደ ጥያቄ ቁጥር 3.29 ይቀጥሉ* ☐ No (2)*[move to 3.34] ወደ ጥያቄ ቁጥር 3.34ይቀጥሉ*
3.28	How do you normally treat the child with diarrhoea? ሕፃኑ ልጅ ተቅማጥ በያዘው ጊዜ ያስታመሙት በ ምን አይነት መንገድ ነው *(check all that apply)አንድ ምርጫ ብቻ ይምረጡ* *DO NOT SHOW THE OPTIONS!*ምርጫዎቹንእንዳያሳዩ!	☐ Went to health facility / ሆስፒታል በመውሰድ (1) ☐ Bought drug at the counter /ከፋርማሲ መድሐኒት በመግዛት(2) ☐ Used traditional medicine/ባህላዊ መንገድ በመጠቀም (3) ☐ Church, mosque or other religious centres/ወደ ሀይማኖታዊ ቦታዎች በመውሰድ (4) ☐ Others Specify (5) ሌላ (ይ ግ ለ ፁ) ....
3.29	How long does he/she stay in facility? ሆስፒታል ወስደውት ከሆነ እዛ ለስንት ጊዜ ቆየ	☐ Ambulatory /ታክሞ መመለስ ☐ Hospitalization/health facility/ሆስፒታል ተኝቶ መታከም/ጤና ጣቢያ ( ) days/ቀናት
3.30	How much do you normally pay for the treatment of your child with diarrhoea per epdisode? ለሕክምናው ስንት ብር ከፈሉ **Note to Enumerator/ማስታወሻ ለ መረጃ ሰብሳቢው* *: The cost includes consultation, examination (laboratory),*	( ) birr/ብር

	hospitalization, medicine, treatment at home and excludes *accommodation and* *transportation./ከፍያው የመጓጓዣ እና ሌሎች ማሚያ ከፍያዎችንአያካትትም*	
3.31	How do you transport to the place you mentioned in 3.28? ሕፃኑን ወደ ህክምናቦታ የወሰዱት በምን ዓይነት መÕÕዣ ነው	☐ Walking/በእግር (1) ☐ Traditional "ambulance" (4 people in group carrying the patient on bed)/በቃሬዛ (2) ☐ Public Transport/በህዝብ መጓጓዣ(3) ☐ Government ambulance /የመንግስት አምቡላንስ(4) ☐ Others Speficyሌላ(ይግለፁ) (5) ....
3.32	How much do you pay for the transportation (round-trip)? በመጓጓዘዣ ደርሶ ለመመለስ ስንት ብር ከፈሉ	( ) Birr/ብር
3.33	How much do you pay for the accommodation? ለሌላ ነገሮች ስንት ብር አወጡ	( ) Birr
3.34	Normally, do you treat yourself with diarrhoea? ተቅማጥ ሲይዝዎ እራስዎን ያስታምማሉ	☐ Yes/አዎ(1)*[move to 3.35]ወደ ጥያቄ ቁጥር 3.35 ይቀጥሉ* ☐ No/አላስታምምም(2)*[move to 3.39]ወደ ጥያቄ ቁጥር 3.39 ይቀጥሉ*
3.35	How do you normally treat yourself with diarrhoea? ለመጨረሻ ግዜ እርስዎ ተቅማጥ የታመሙ ጊዜ ምን አደረጉ *(check all that apply)አንድ ምርጫ ብቻ ይምረጡ* *DO NOT SHOW THE OPTIONS!*ምርጫዎቹንእንዳያሳዩ!	☐ Went to health facility/ሆስፒታል በመውሰድ (1) ☐ Bought drug at the counter /ከፋርማሲ መድሐኒት በመግዛት(2) ☐ Used traditional medicine/ባህላዊ መንገድ በመጠቀም (3) ☐ Church, mosque or other religious centres/ወደ ሀይማኖታዊ ቦታዎች በመውሰድ (4) ☐ Others Specify (5)ሌላ(ይግለፁ).........................

3.36	How long do you stay in hospital? ሆስፒታል ሔደው ከሆነ እዛ ለስንት ጊዜ ቆዩ	☐ Ambulatory /ታክሞ መመለስ ☐ Hospitalization/health facility ሆስፒታል /ጤና ጣቢያተኝቶ መታከም( ) days/ቀናት
3.37	On the average how many days are you sick per each episode of diarrhoea? እርስዎን ተቅማጥ በሚይዝዎት ጊዜ በአማካኝ ለስንት ቀናት ይታመማሉ	( ) days/ቀናት
3.38	How much do you normally pay for the treatment of yourself with diarrhoea per episode? ለሕክምናዎ ስንት ብር ከፈሉ **Note to Enumerator/ማስታወሻ ለ መረጃ ሰብሳቢው* *: The cost includes consultation, examination (laboratory), hospitalization, medicine, treatment at home and excludes accommodation and transportation./ክፍያው የመጓጓዣ እና ሌሎች ማሚያ ክፍያዎችንአያካትትም*	( ) Birr/ብር
3.39	Can you explain how human faeces affect hygiene and health when they are not well managed?Explain how. የሰው ዓይነምድር በተገቢው ሁኔታ ካልተወገደ የሰውን የግል ንፅህና እና ጤና በምን አይነት መንገድ እንደሚጎዳ ሊያስረዱኝ ይችላሉ *(Write all responses, and then probe with 'what else?'))ሁሉንም ምላሾች ከፃፉ በኋላ ሌላስ ብለው ይጠይቁ*	i……………………………………………………… ii……………………………………………………... iii……………………………………………………..
3.40	Can you explain how to handle human faeces in a hygienic way? የሰው ዓይነምድር ለማስወገድ ተገቢው መንገድ ምን እንደሆነ ሊያስረዱኝ ይችላሉ	i………………………………………………… ii……………………………………………

(Write all responses, and then probe with 'what else?'))ሁሉንም ምላሾች ከፃፉ በኋላ ሌላስ ብለው ይጠይቁ

iii……………………………………………..

3.41 Can you explain how to build latrine at your house to handle your faeces in a hygienic way?

የሰው ዓይነምድር በተገቢው መንገድ ለማስወገድ የመፀዳጃ ቤት አገነባብ እንዴት እንደሆነ ሊያስረዱኝ ይችላሉ

((check all that apply)) የሚስማሙትንሁሉይምረጡ

*DO NOT SHOW THE OPTIONS!*ምርጫዎቹንእንዳያሳዩ!

- [ ] Pit hole with proper depth/አስተማማኝ የሆነ የመፀዳጃ ጉድጓድ ጥልቀት(1)
- [ ] Cleanable/washable slab/ለማፅዳት ምቹ የሆነ…….ማዘጋጀት(2)
- [ ] Cover for drop-hole / Ki"ƒ u?~ Ñ<`ÕÉ kÇÇ ¡Ç" TuËƒ(3)
- [ ] Wall/ግድግዳ ማኖር(4)
- [ ] Roof /ጣርያ ማኖር(5)
- [ ] Hand washing facility/የእጅ መታጠቢያ ቦታ ማዘጋጀት(6)

④ Household Socio-Economic Data

4.1 What is the marital status of the respondent?

የተጠያቂው የጋብቻ ሁኔታ

(check only one option)አንድ ምርጫ ብቻ ይምረጡ

- [ ] Single/ያላገባ (1)
- [ ] Married/ያገባ(2)
- [ ] Widowed/በሞት የተለየ(3)
- [ ] Divorced/የተፋታ(4)
- [ ] Separated/ለጊዜው የተለያየ(5)

4.2 Which ethnicity is the household head?

- [ ] Gurage/ጉራጌ(1)
- [ ] Amhara/አማራ(2)

	የቤተሰቡ ብሔር ምንድነው	☐ Hadiya/ሀድያ(3)
		☐ Tigray/ትግሬ(4)
	(check only one option)አንድ ምርጫ ብቻ ይምረጡ	☐ Other (Specify)ሌላ(ይግለፁ) (5)______________________
		☐ Refused to say /መናገር አልፈልግም(999)
4.3	What is the level of education of the respondent? የተጠያቂው የትምህርት ደረጃ *((check only one option)አንድ ምርጫ ብቻ ይምረጡ*	☐ Illiterate/ያልተማረ (0) ☐ Read & Write/ማንበብ እና መፃፍ(1) ☐ 1-4 Grade/ከ1-4 ክፍል(2) ☐ 5-8 Grade/ከ5-8 ክፍል(3) ☐ 9-10 Grade/ከ9-10 ክፍል(4) ☐ 11-12 Grade/ከ11-12 ክፍል(5) ☐ College & Above/ኮሌጅ እና ከዛ በላይ(6)
4.4	What is the ***primary*** occupation of the head of household? የቤተሰቡ ሀላፊ ስራ ምንድነው *(check only one option)አንድ ምርጫ ብቻ ይምረጡ*	☐ Unemployed/ስራ የለውም(0) ☐ Farmer/አርሶ አደር(1) ☐ Trader/ነጋዴ(2) ☐ Store owner /የሱቅ ባለቤት (3) ☐ Unskilled labourer ባለሙያ ያልሆነ የቀን ሰራተኛ(4) Skilled labourer/Artisansባለሙያ የሆነ ሰራተኛ (5) ☐ Factory worker/የፋብሪካ ሰራተኛ (6) ☐ Professional, e.g. teacher, doctor, engineerባለበት ሙያ የሰለጠነ(ምሳሌ.አስተማሪ፣ሀኪም፣ኢንጅነር) (7) ☐ Military /ወታደር(8) ☐ Housewife (unpaid)/የማይከፈላት የቤት እመቤት (9) ☐ Other /ሌላ(10) ____________________________

4.5	What is the religion of the head of household? የቤተሰቡ ሃላፊ ሃይማኖት ምንድነው *(check only one option)አንድ ምርጫ ብቻ ይምረጡ*	☐ Not Religious/*ሀይማኖት የለውም* (0) ☐ Christian /ክርስቲያን(1) ☐ Muslim /*ሙስሊም*(2) ☐ Traditional Religion/ባህላዊ *ሀይማኖት* (3) ☐ Other /ሌላ(4) ☐ Refused to say/*መናገር* አልፈልግም (9)
4.6	How many people currently live in your household? በአሁኑ ሰአት ስንት ሰው በቤት ውስጥ ይኖራል	…………..*People/ሰዎች*
4.7	How many of these members are children **under the age of five** (5)? ካሉት ሰዎች መሀል ከ 5 አመት በታች የሆኑት ስንት ናቸው	…………*Children/ሕፃናት*
4.8	What type of house do you live in? ምን አይነት ቤት ውስጥ ነው የሚኖሩት *(check only one option)አንድ ምርጫ ብቻ ይምረጡ*	☐ Thatched Roof/ጎጆ ቤት (1) ☐ Corrugated Iron Sheet Roof & soil floor/የቆርቆሮ ክዳን እና የአፈር መሬት ያለው (2) ☐ Corrugated Iron Sheet Roof & Cemented floor/ የቆርቆሮ ክዳን እና የሲሚንቶ መሬት ያለው (3) ☐ Others (specify) (4)ሌላ(ይገለፅ) ________________
4.9	Do you share your living quarter with animal? ቤትዎ ውስጥ እንሰሳቶችም ይኖራሉ	☐ Yes/አዎ(1) ☐ No/አይኖሩም(2)
4.10	What is the average household expenditure **per month**? በወር ውስጥ በአማካኝ ለቤት ወጪ ምን ያህል ብር ያወጣሉ	……..............……Birr/Month/ብር በወር .... Birr/Year/ብር በዓመት
		☐ Water/ለውሃ (1) ☐ Sanitation and Hygiene/ለንፅህና (2)

4.11	Approximately, how much do you spend on the following items for the household **per month?** **<u>ለተዘረዘሩት ነገሮች በወር ምን ያህል ብር ያወጣሉ</u>** *(Please state for those that applyለተመረጡት)ምን ያህል ብር እንደሚወጣ ይገለፅ*	[ ] [ ] [ ] [ ] [ ] [ ]	Food/ለምግብ(3) Health/ለጤና(4) Electricity and light/ለኤሌትሪክ እና መብራት (5) Children's education/ለልጆች ትምህርት(6) House rent/ለቤት ኪራይ(7) Others (specify)/ሌላ(ይገለፅ) (9)______________
4.12	How much do you earn (cash) in **<u>a month and in a year</u>**? በወር ምን ያከል ብር ያገኛሉ ፣ በአመትስ		……...............……Birr /Month/ብር በወር .... Birr/Year/ብር በአመት
4.13	Approximately, how much do you earn on the following items for the household **<u>per year?</u>** *(Please state for those that apply)* *ከጎን ለተዘረዘሩት ነገሮች በአመት ውስጥ በአማካይ ምን ያከል ብር ያወጣሉ* *(እባከዎን የሚስማማውን ይዘርዝሩ)*		Food production for subsistence/ለምግብ...............……Birr/ብር Cash Crop production/ለሰብል ምርት...............……Birr/ብር Livestock & Animal products /ለ ከብቶች እና ውጤቶቻቸው...............……Birr/ብር Unskilled labour/ለጉልበት ሰራተኛ...............……Birr/ብር Handycraft ....……Birr/ብር Salary/ደመወዝ...............……Birr/ብር Remittance/ብድር...............……Birr/ብር Petty Trade /ጥቃቅን ወጪዎች...............……Birr/ብር

Thank you very much for your participation. This is the end of the interview.If you have any question about the study, please feel free to task. ለ ተሳትፎ በጣም አመሰግናለሁ፡፡ ቃለመጠይቁ በዚህ ያበቃል፡፡ ስለጥናቱ ጥያቄ ካሎት ካለምንም ታቅቦ ሊጠይቁኝ ይችላሉ

Time Finished: __የተጠናቀቀበት ሰዓት፡ --------

Appendix 2. Letter of ethical approval from the Ministry of Science and Technology, Ethiopia

በኢትዮጵያ ፌዴራላዊ ዴሞክራሲያዊ ሪፐብሊክ
የሳይንስና ቴክኖሎጂ ሚኒስቴር
The Federal Democratic Republic of Ethiopia
Ministry of Science and Technology

ቁጥር 3.10/032/2015
Ref. No.
ቀን July 29-2015
Date

To: Korea International Cooperation Agency Ethiopia Office
Addis Ababa, Ethiopia

Re: The health and economic impact of improved sanitation on the reduction of diarrheal disease of under-five children in Gurage Zone, SNNPR state, Ethiopia

Dear Sir/Madam//Mr./Mrs./Dr,

The National Research Ethics Review Committee (NRERC) has reviewed the aforementioned project protocol in an expedited manner. We are writing to advise you that NRERC has granted

Full Approval

To the above named project, for a period of **one year (July 29, 2015- July 28, 2016).** All your most recently submitted documents have been approved for use in this study. The study should comply with the standard international and national scientific and ethical guidelines. Any change to the approved protocol or consent material must be reviewed and approved through the amendment process prior to its implementation. In addition, any adverse or unanticipated events should be reported within 24-48 hours to the NRERC. Please ensure that you submit biannual progress report once in six months and annual renewal application 30 days prior to the expiry date.

We, therefore, request you as PI and your esteemed organization to ensure the commencement and conduct of the study accordingly and wish for the successful completion of the project.

[redacted]

Yohannes Sitotaw
Secretary of NRERC

CC. _ SNNPR State Health [redacted]
_ Dr. Seungman Cha ([redacted]

ማነጋገር ቢያስፈልግዎ
You may Contact

ፖ.ሳ.ቁ. P.O.Box 2490	አዲስ አበባ ኢትዮጵያ Addis Ababa, Ethiopia E-mail most@ethionet.et	ስልክ Tel. 251-011-4-674353 Web site:-http://www.most.gov.et	ፋክስ Fax +251-011-4-66 02 41

Appendix 3. Letter of ethical approval (LSHTM)

London School of Hygiene & Tropical Medicine
Keppel Street, London WC1E 7HT
United Kingdom
Switchboard: +44 (0)20 7636 8636

www.lshtm.ac.uk

Observational / Interventions Research Ethics Committee

Dr. Seungman Cha
LSHTM

22 February 2019

Dear Seungman,

Study Title: Evaluation of a community-led total sanitation intervention in a rural area of the SNNPR state, Ethiopia

LSHTM Ethics Ref: 16260

Thank you for your application for the above research project which has now been considered by the Observational Committee via Chair's Action.

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation, subject to the conditions specified below.

Conditions of the favourable opinion

Approval is dependent on local ethical approval having been received, where relevant.

Approved documents

The final list of documents reviewed and approved is as follows:

Document Type	File Name	Date	Version
Local Approval	4. IRB approval letter	29/07/2015	1
Protocol / Proposal	study protocol_SNNPR	18/04/2016	final
Investigator CV	DrPH candidate_Seungman Cha	17/12/2018	1
Consent form	Informed Consent Form	29/12/2018	1
Protocol / Proposal	Survey Questionnaire	29/12/2018	1
Protocol / Proposal	Diarrhea Calendar	29/12/2018	1

After ethical review

The Chief Investigator (CI) or delegate is responsible for informing the ethics committee of any subsequent changes to the application. These must be submitted to the committee for review using an Amendment form. Amendments must not be initiated before receipt of written favourable opinion from the committee.

The CI or delegate is also required to notify the ethics committee of any protocol violations and/or Suspected Unexpected Serious Adverse Reactions (SUSARs) which occur during the project by submitting a Serious Adverse Event form.

An annual report should be submitted to the committee using an Annual Report form on the anniversary of the approval of the study during the lifetime of the study.

At the end of the study, the CI or delegate must notify the committee using the End of Study form.

All aforementioned forms are available on the ethics online applications website and can only be submitted to the committee via the website at: http://leo.lshtm.ac.uk.

Further information is available at: www.lshtm.ac.uk/ethics.

Yours sincerely,

[redacted]

Professor John DH Porter
Chair

ethics@lshtm.ac.uk
http://www.lshtm.ac.uk/ethics/