



Contents lists available at ScienceDirect

International Journal of Hygiene and Environmental Health

journal homepage: www.elsevier.com/locate/ijheh

A framework for targeting water, sanitation and hygiene interventions in pastoralist populations in the Afar region of Ethiopia

Lucy Whitley^a, Paul Hutchings^{a,*}, Sarah Cooper^a, Alison Parker^a, Abinet Kebede^b, Solome Joseph^c, John Butterworth^b, Barbara Van Koppen^d, Adolph Mulejaa^e

^a School of Water, Energy and Environmental (SWEE), Water Science Institute, Cranfield University, Cranfield, MK, 43 0AL, United Kingdom

^b IRC Ethiopia, Golagul Towers Building, Bole sub city, Woreda 4 H.No. 275/276, Addis Ababa, Ethiopia

^c Friendship Support Association, Nefas Selek Lafto Sub-city, Woreda 02, Mekanisa S. Sara building. P.O.Box 22068, code 1000, Addis Ababa, Ethiopia

^d International Water Management Institute, 5. International Water Management Institute, 127, Sunil Mawatha, Pelawatte, Battaramulla, Sri Lanka, (IWMI)

^e Nanotechnology and Water Sustainability (NanoWS) Research Unit, College of Science, Engineering and Technology, University of South Africa, Florida Campus, Johannesburg, 1710, South Africa



ARTICLE INFO

Keywords:

Pastoralists
WASH
Behaviours
Risk
Pathogens
Ethiopia

ABSTRACT

Globally, many populations face structural and environmental barriers to access safe water, sanitation and hygiene (WASH) services. Among these populations are many of the 200 million pastoralists whose livelihood patterns and extreme environmental settings challenge conventional WASH programming approaches. In this paper, we studied the Afar pastoralists in Ethiopia to identify WASH interventions that can mostly alleviate public health risks, within the population's structural and environmental living constraints. Surveys were carried out with 148 individuals and observational assessments made in 12 households as part of a Pastoralist Community WASH Risk Assessment. The results show that low levels of access to infrastructure are further compounded by risky behaviours related to water containment, storage and transportation. Additional behavioural risk factors were identified related to sanitation, hygiene and animal husbandry. The Pastoralist Community WASH Risk Assessment visually interprets the seriousness of the risks against the difficulty of addressing the problem. The assessment recommends interventions on household behaviours, environmental cleanliness, water storage, treatment and hand hygiene via small-scale educational interventions. The framework provides an approach for assessing risks in other marginal populations that are poorly understood and served through conventional approaches.

1. Introduction

Contributing to improved public health, nutrition, education and equality, access to safe drinking water, effective sanitation systems and good hygiene practices (WASH) plays a huge role in the global movement towards achieving the Sustainable Development Goals (SDGs). The Joint Monitoring Programme (JMP), reporting on the progression of WASH across the SDG regions, concluded that almost 581 million people are still collecting drinking water from surface water or unprotected groundwater sources and a further 892 million people are still practising open defecation (WHO and UNICEF, 2017a). These unsafe sources and practices increase exposure to pathogens (disease-causing bacterial, viral or parasitic organisms) and are a cause of serious public health issues. The pathogens of concern are mainly transmitted through faeces in the environment leading to diarrhoeal diseases, which on a

global level contribute to 2.2 million deaths every year; a quarter of which are children under the age of 5 years (WHO, 2017). An analysis of data by Prüss-Ustün et al. (2014) estimated that 58% of diarrhoeal diseases in 2012 were the result of a cluster of risks associated with inadequate WASH facilities. Occurring when the gastrointestinal tract of a host becomes infected, the extent of the infection is influenced by the strength of the host's natural defences and the virulence of pathogens. Marginal populations who live in poor conditions, lack healthcare and face constant inadequate nutrition, stress and fatigue have weakened immune systems and are more vulnerable to infection. The continuous exposure to faecal pathogens causes gut inflammation, diarrhoeal episodes and dehydration, and is further linked to malnutrition and poor child development, such as stunted growth (Ngure et al., 2014).

Pathways of faecal pathogen transmission are well known and

* Corresponding author.

E-mail address: p.t.hutchings@cranfield.ac.uk (P. Hutchings).

<https://doi.org/10.1016/j.ijheh.2019.08.001>

Received 29 March 2019; Received in revised form 1 August 2019; Accepted 3 August 2019

1438-4639/© 2019 The Authors. Published by Elsevier GmbH. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

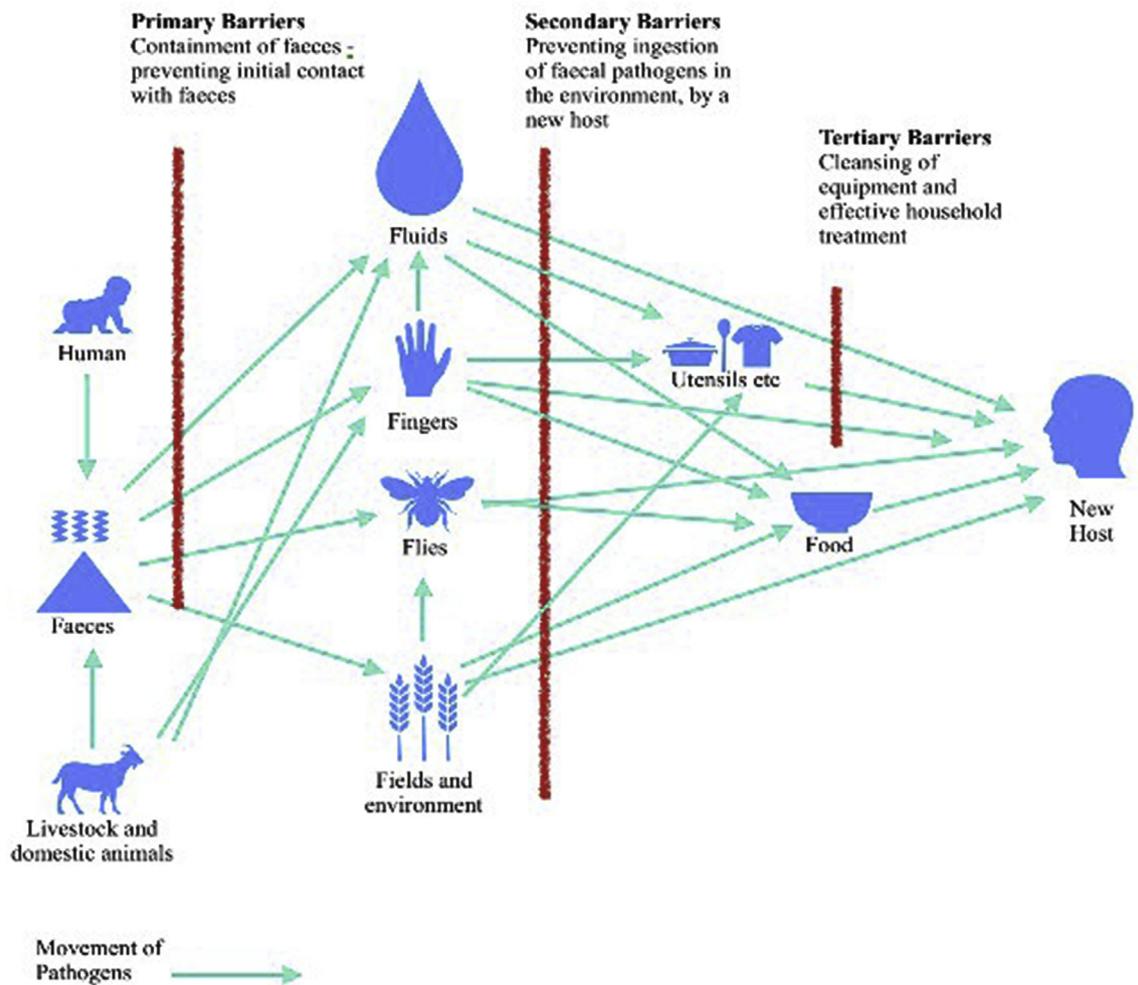


Fig. 1. F-diagram demonstrating possible transmission routes for faecal pathogens.

commonly represented in the 'F-diagram'; a diagram used to highlight faecal-oral transmission routes (see Fig. 1). Transmission routes are blocked or at least narrowed through specific domestic practices, improved infrastructure and protection of water sources. Sanitation, the primary barrier, can isolate faecal pathogens to stop them from reaching the environment. Secondary barriers, such as water treatment and handwashing, stop faecal pathogens in the environment from multiplying and reaching new hosts and tertiary barriers stop faecal pathogens, such as those on household utensils, from reaching the host (Curtis et al., 2000). However, recent reports are beginning to question whether sanitation facilities are effective measures to act as the first port of call to interrupt the transmission of faecal pathogens. A sanitation intervention trial in India found that increased latrine coverage did not reduce exposure to faecal contamination or prevent diarrhoea, soil-transmitted helminth infection, or child malnutrition (Clasen et al., 2014), and further recent control trails showed little to no effect from sanitation interventions on child health (Luby et al., 2018; Null et al., 2018). Increasingly, the role of animal faeces is being recognised as another important source of faecal pathogens, especially in animal rearing populations (Budge et al., 2019; Penakalapati et al., 2017), leading people to rethink the faecal pathogen transmission pathways and the types of interventions needed to address them. Pastoralists, that number around 200 million worldwide and 12 million in Ethiopia, are likely to be at even higher risk than non-animal rearing populations to this particular animal-human pathway.

As well as the direct impact of water-borne infections on health, there is an emerging evidence-base that indicates that chronic exposure

to faecal pathogens in the environment leads to enteric inflammation in children that reduces nutrition absorption and negatively impacts growth (Keusch et al., 2013; Mosites et al., 2017). Known as Environmental Enteric Dysfunction (EED), this condition represents a largely sub-clinical disorder in that subjects show no obvious symptoms such as diarrhoea, and as such it has been called the potential 'missing piece of the stunting puzzle' (Budge et al., 2019). The precise aetiology of EED is still being determined with limited evidence on prevalence and incidence, as well as on the role of specific pathogens and their exposure and dosage thresholds (Watanabe and Petri, 2016). However, the prevailing understanding is that faecal pathogen exposure, especially from animal sources, leads to the described gut inflammation. EED and its associated evidence-base provides another strong justification for assessing and mitigating faecal pathogen exposure risks in vulnerable populations and taking pragmatic steps to reduce pathogen exposures within and around the home.

In Ethiopia, pastoralists are amongst the most poorly served population in a country that has extremely low levels of WASH access compared to international standards. According to the most recent JMP report, 44% of rural Ethiopians are still collecting water from a surface water source or an unprotected groundwater source (unimproved service) (WHO and UNICEF, 2017a), such as rivers, ponds, scoop holes and springs. On top of this, only 4% of rural Ethiopians use safely managed sanitation, 32% open defecate and 99% have no hygiene facilities. Furthermore, in the pastoral context, with water sources few and far between, there are considerable opportunities for faecal contamination of water between the point of collection and point of consumption. This

means not only are pastoralists faced with drinking contaminated water at source, it is likely that the water they transport, store and handle, suffers from secondary contamination (Kassie and Hayelom, 2017). Despite pastoralists being at particularly high risk, specific pastoral interventions for sanitation and hygiene development are few, partly because of the itinerant lifestyle of the people and the limited sector knowledge of their practices and behaviour.

To help provide an improved evidence base for workable WASH intervention design in pastoralist populations, the study aims to answer the following questions: What risks do pastoralists face in relation to their water handling, sanitation and hygiene practices? And what interventions can be identified to best address these risks within the operating context of the Ethiopian lowlands? In answering these questions, the paper also seeks to present a way to identify and assess such risks for other marginal populations that are poorly understood and commonly served through conventional WASH sector thinking. To help address this aim, and building on the evidence presented above and the work of Penakalapati et al. (2017) and Budge et al. (2019), we present an adapted F-diagram for the pastoralist context (as shown in Fig. 1). This illustrates that animal faeces are a source of pathogen transmission as well as humans, and we use this as a foundational framework to inform our understanding of faecal-oral transmission routes throughout the study.

2. Material and methods

2.1. Study context

The research was based on primary data collected from three villages in the Dulassa Woreda within Administrative Zone Three of Afar State. The Afar region in eastern Ethiopia is home to around 1.3 million of the estimated 12 million pastoralists in Ethiopia (Afar National Regional State, 2010), and is part of the broader arid and semi-arid lowlands region of Ethiopia. This region has always experienced extreme rainfall variability, drought and occasional floods, yet climate change and increasing population densities are putting additional pressure on dwindling water resources. This has led to a chronic dependency on water trucking and government aid to sustain part of the population that, even with this support, live with high levels of poverty and access to services; well below those aspired to under the SDGs.

The lowland area is not only divided into administrative zones but on a cultural level, there are clan and sub-clan territories where the minutiae of resource access, land use, hierarchy and roaming customs are negotiated through customary arrangements. Water associated labour is strictly gendered with women responsible for domestic supplies and young animals, and adult men responsible for adult herds, especially cattle and camels. Another important aspect of the water management processes in the region is connected to the seasonality of supplies and, relatedly, the seasonal variation in rangeland availability for cattle and other pastoralist reared animals. The short rainy season(s) known as '*karma*' in Afar, is when pastoralists have sufficient water to meet their needs, and can be as little as a one week period. During this time when water is more accessible, pastoralists can range farther for more nutritious pasture for their livestock. In the dry season when pasture and water is deficient, pastoralists tend to congregate near to more permanent water sources if they exist. The specific Afar pastoralist system in this study can be described as transhumance in character. Although they have semi-permanent villages, they solely rely on livestock for their livelihood and follow seasonal roaming patterns in search of grazing lands and water. In the Afar, these annual routines have more recently been stressed, not only by climatic changes and more infrequent rainfalls, but also by state construction, irrigation and economic development projects, such as the current construction of the railway line from Addis Ababa to Djibouti and upstream polluting activities. In this sense, many pastoralists live in the precarious situation of being reliant on government support, but are also having their

customary management systems disrupted by broader development initiatives.

The government of Ethiopia is currently launching a new public policy programme with collaboration from the donor community, called the Climate Resilience Programme for Water, Sanitation and Hygiene. The programme aims to overhaul the current WASH systems mainly through the creation of large-scale water infrastructure (e.g. multi-village water schemes), which is a new approach for the region. This context provides the backdrop to this paper's contribution. The intention is to better understand what small-scale steps can be taken in pastoralist communities to improve public health outcomes via WASH interventions within the conventional restraints of the environment, whilst acknowledging and supporting these broader 'macro-level' efforts to transform the regions water infrastructure and services.

2.2. Study design

This study has two elements of data collection, closely connected to one another. The first, a quantitative survey which focused on water consumption and sanitation and hygiene practices and the second, household observations based on a prepared risk assessment checklist focusing on household and environmental hygiene (see supplementary information to review the data collection tools). Quantitative surveys were performed with 148 individuals from three communities. Detailed household observations and informal questioning were carried out with 12 heads (male and female) of households. The study took place in three communities (Adkonta, Tirtira and Ege) in the Tirtira Kebele of the Dulassa Woreda. The villages were initially chosen to account for different levels of access to improved water sources, however between the scoping visit for village selection (March 2018) and the main data collection period (June 2018), the improved water source (borehole) that was available in one of the villages failed. As a result, all villages were predominately reliant on unimproved water sources during the data collection period. The communities had similar contextual factors, such as clan and sub-clan membership, population size, wealth and mix of ages. This meant that the three communities were homogenous in terms of WASH access and socio-cultural markers and, as such, the data were analysed at a generalised level across all villages.

The survey involved quantitative closed questions on household water sources, water use, accessibility and quantity, as well as questions around latrine access, safety and hygiene. The quantitative surveys were also used to measure basic socio-demographics of households. Household observations and informal questioning were conducted using an observation checklist to assess possible indicators of faecal pathogen transmission routes in relation to the WASH behaviours, surrounding environment and the built environment of pastoralists. Observations were made during the daytime only, and as such, night time practices were not captured, which could imply an under-estimation of certain risks such as animal presence in the household overnight. The checklist was designed based on a review around sanitary surveys and critical household indicators such as cleanliness, hygiene and equipment observations (e.g. WHO, 2011). It consisted of multiple answer observation checks as well as follow-up questions to be asked if necessary. Photographs were also taken when possible.

2.3. Data collection and analysis

A research team of five enumerators were enlisted as part of the data collection team. The quantitative survey was designed in English and translated into Afar with a pilot study conducted on six households allowing enumerators to build confidence and clarify any cultural or language misinterpretations. Face-to-face interviews were carried out and the survey responses were recorded using mWater; a digital WASH data collection software accessible on hand-held tablets (mWater, no date). Sampling was designed based on random sampling at the household level, with both female head and male head surveyed in each

household wherever possible (total sample includes 54% male and 46% female). As has been the case with similar studies of pastoralist communities, the implementation of random sampling approach was challenged by respondents being dispersed across large rangelands meaning that the approach shifted towards a convenient sampling approach in the field. With the village populations between 50 and 80 households, the relative size of the survey samples (38, 54 and 56) indicates the data are still fairly representative of the population. The lead author and accompanying researchers conducted the household observations in which they visited homes, discussed and observed water handling, sanitation and hygiene practices with purposively selected households, spending a period of 60 min with each household. The study focused on the residential areas in the three villages. Specific issues that pastoralists encounter when they travel with their animals to pastures and rely on other water sources are not addressed. The sampling strategy for the household observation was organised in parallel but independently to the surveying sampling. The respondents were chosen based on availability and convenience with no further inclusion criteria beyond being residents of the villages. Due to the homogeneity in household type and livelihood within this populations this approach still provides an overview of risks related to household WASH practices in pastoralist communities.

During the data collection period, the research lead ensured survey completion and consistency by syncing data within the mWater software, daily. Concluding the data collection period, data stored were downloaded into an Excel database for basic descriptive statistical analysis. Data collected from the household observations was brought together manually and also entered into an Excel database for analysis. A Pastoral Community WASH Risk Assessment Analysis was created to analyse and interpret the seriousness of risks against the difficulty of addressing the problem, with both survey and observation data processed via this framework. The imbalance in sample sizes between the survey ($n = 148$) and observations ($n = 12$) limits the ability to specifically analyse sub-groups via the framework. However, the intention was to provide a generalised analysis of possible pathways of faecal contamination within the pastoral behaviours, environment and built environment, which the data has allowed us to make.

The approach adapted ideas from WASH-FIT (Water and Sanitation for Health Facility Improvement Tool, 2017), a tool developed to address the gaps, initiate improvements and sustain WASH in healthcare facilities in low and middle-income countries, developed by the World Health Organisation and UNICEF (WHO and UNICEF, 2017b). The basis of WASH-FIT was applied because of its focus on WASH and behaviours when resources are limited. We built on the logic the tool followed in terms of assessment, ranking of risks, and defining incremental steps to reduce risk. We believe that the Pastoral Community WASH Risk Assessment (see Table 1), designed to be indicative rather than exhaustive, serves as a tool that could be adapted for other pastoral communities. The essential indicators were synthesised to reflect the Ethiopian National standards as formulated from Ethiopia's Growth and Transformation Plan II (GTP II) (Ministry of Water, 2015) and specifics of best practice from literature, for example 'Water Drawing: Water is poured directly from storage container to drinking vessel' (WHO, 2013) and 'Guidelines for Water Quality' (WHO, 2011). The essential indicators are graded as to whether the pastoral community meets the target, partially meets the target or does not meet the target, using the data collected. Each indicator has supporting comments to help decide if the targets are met or not (Tables 1 and 2). A score is given, and hazards and risks outlined, thereafter giving a seriousness of risk grading in accordance to the key. The difficulty of addressing the problem is a judgement made at the discretion of the analyser, but is graded with three focal areas; technical skill needed, estimated costs and behavioural difficulties of addressing the problems. An average score is taken and the difficulty of addressing the problem is given a high, medium or low score. These scores are placed onto an overall grid to illustrate specific areas where exposure pathways and pathogen

hazards in a pastoral setting present risk. We recognise that leaving this assessment to the subjectivity of the user means that there can be inconsistencies in such judgements. However, we aspire for the tool to be used by practitioners and believe this flexibility is a strength as it allows them to make judgements that reflect their own operational capacity.

2.4. Ethical approval and permission

The study was reviewed, and ethical approval was obtained from Cranfield University Ethical Review Systems [CURES/3724/2018]. Permission to conduct surveys in the communities was obtained from Dulassa Woreda (district) government office and respective individuals being questioned. Oral informed consent presentations were given at the start of each survey and observation demonstrating the reasons behind the research and outlining the rights of the respondent.

3. Results and discussion

This combined results and discussion section is divided into three. The first section provides an overview of domestic water, sanitation and hygiene conditions and practices within the villages. The second section interprets this through the risk assessment process. From that analysis, hazards and risks are highlighted and the difficulty of addressing the problem is considered, leading to identification of intervention areas to be prioritised. The final section discusses the implications for intervention design and the limitations of the study.

3.1. Water supply

Seasonal differences are a defining aspect of pastoralist water use in the studied villages. Of the 148 individuals surveyed, 68% used surface water sources as their primary source of water for domestic use during the rainy season (38% rivers, 30% ponds) whilst 26% reported to use a motorised borehole ($n = 148$). During the dry season 35% of the study population used hand dug wells and 35% used scoop holes, and the remaining 30% used a motorised borehole ($n = 148$). Nearly three quarters of respondents (73%) reported that their primary water source for domestic use did not provide them with water every day during the dry season ($n = 148$).

During the rainy season, 38% of respondents take less than 30 min to reach their water source and return ($n = 148$). The remainder take more than 30 min for a round trip (Fig. 2). At the other end of the scale, a huge difference in collection time and therefore labour time, was seen during dry season. Less than 1% take under 30 min to reach and return from the water source, additionally 61% of respondents spend more than 4 h walking to an unimproved water source ($n = 148$). A chi-squared test showed a significant difference in water collection time between rainy and dry season; chi-square value of 134.05 with $p < 0.05$.

Ethiopia's Growth and Transformation Plan II (GTP II) (Ministry of Water, 2015) highlights 25 L per capita per day as a minimum standard for water quantity. In the rainy season 67% of the study population are collecting less than this amount whilst this is a similar proportion during the dry season (65%). The mean quantity of water collected per capita per day in rainy season is 26 L and in dry season 20 L ($n = 148$); although when using the median this falls to 16 and 13 L, respectively. This indicates that there are some households that collect a large volume of water compared to others. We associate this with those households that are have larger water collection containers and more donkeys to use when collecting water. There was no statistically significant difference in the mean quantity of water collected in the rainy season and dry season ($p = 0.89887$ at $p < 0.05$). This indicates that pastoralists are collecting similar amounts of water in each season but that they must spend much longer collecting and transporting in the dry season, which has implications not only for their labour and wellbeing, but also in terms of secondary contamination risks.

Table 1
Pastoral community WASH risk assessment framework – water and sanitation.

Essential Indicator	Meets the target +++	Partially meets the target ++	Does not meet the target +
WATER			
1.1 Water Source	Water is collected from an improved source where water is available when needed, free from contamination.	Water is available from an improved source for only part of the year, the source is not reliable.	Water is collected from an unimproved or surface water source.
1.2 Water Quantity	Water quantity collected meets a minimum of 25 l/c/d.	Water quantity collected is less than 25 l/c/d but meets the individuals' demands for domestic water needs, all year round.	Water quantity collected is not sufficient to meet the domestic water needs of the individuals, all year round.
1.3 Water Transportation	Water is collected from a source within a 1 km radius of the community settlement.	Water source is within 1 km radius of the community settlement, but the community had to move specifically closer to the source.	Water source is outside a 1 km radius of the community settlement.
1.4 Household Water Storage Container	Drinking water is stored in a sealed, covered, visibly clean, durable container.	Water container displays visible signs of dirt build-up or algae inside and around the spout area, but a lid, cap or tie is present.	Water container displays visible signs of dirt build-up or algae inside and around the spout area and no lid, cap or tie is present.
1.5 Household Water Storage Location	Water container is stored away from the thoroughfare and out of animals' reach and there is a clear separation between treated and untreated water.	Water container is stored out of animals' reach, but within the thoroughfare area of the house and it is unclear which containers are used for treated and untreated water.	Water container is stored on the floor where animals can reach and touch the container and there is no separation between treated and untreated water.
1.6 Household Water Treatment	Water is treated using standard known household water treatment methods.	Water is treated using Point-of-Use water treatment methods, at all times.	Water is not treated at any time.
1.7 Water Drawing Methods	Water is poured directly from storage container into vessel.	Water is transferred using a dipping method with a clean specific utensil for transferring water.	Water is transferred using a dipping method and utensil used appears unclean and fingers are also in contact with water.
SANITATION			
2.1 Latrine Access	Households have access to an improved latrine as in line with the JMP standards.	Some households have access to an improved latrine.	No households have access to an improved latrine and open defecation is performed.
2.2 Defecation Safety	Individuals feel safe when defecating, particularly women and girls, throughout the day and night and latrines are less than 30 m from the household.	Yes, individuals feel safe when defecating and latrines are within 30 m of the household.	Individuals feel threatened and unsafe when defecating in the day and night, whether open defecating or using a latrine.
2.3 Diarrhoeal Incidences	Individuals report no diarrhoeal incidences within the last month.	Individuals report no diarrhoeal incidences within the last month.	Every member of the household has reported diarrhoeal incidences within the last month.
HYGIENE			
Essential Indicator	Meets the target +++	Partially meets the target ++	Does not meet the target +
3.1 Handwashing Facilities	Basic handwashing facilities are present in every household and water and soap is always available.	Handwashing facilities are present in every household, but water and soap are not available.	No handwashing facilities are present.
3.2 Handwashing Timings	Individuals can specify critical timings for handwashing.	Yes, individuals specify critical timings for handwashing – before eating, before food preparation, after defecation, after animal management, after washing children and before feeding children.	Individuals report that no handwashing takes place. Individuals report handwashing practice but cannot specify critical timings and cannot perform handwashing on every occasion due to the lack of water and soap.
HOUSEHOLD ENVIRONMENT			
4.1 Cleanliness	Households are visibly clean and free from smoke and no flies are visible.	Signs of uncleanness, food is loose, and utensils are not stored in a clean area. There is a bearable amount of smoke and some flies are visible.	Signs of uncleanness, food is loose, and utensils are not stored in a clean area. There are signs of animal or human faeces within the household and an unbearable amount of smoke and flies are visible in all areas.
4.2 Animal Presence	Animals are not kept inside the household.	One young small domestic animal (kid or lamb) is kept inside the household on some occasions but it is secured in one location.	Animals move freely from the inside of the household to the outside and vice versa.

(continued on next page)

Table 1 (continued)

Essential Indicator	Meets the target +++	Partially meets the target ++	Does not meet the target +
4.3 Faecal Presence	Households are free from animal and human faeces (including infant faeces), inside and within a 30-m radius of the household.	Yes, the households are free from animal and human faeces inside and within a 30-m radius of the household.	There are no visible signs of animal or human faeces inside the household, but within a 30-m radius there are signs of animal and/or human faeces.
WATER			There are signs of animal and human faeces inside and outside the household.

The study revealed that jerry cans were the most preferred container for water collection and storage (61%; n = 148), ranging in volume from 5 to 25 L. A goat skin (called a *sar* in Afar) sewn securely into a sack like container was also used by 36% of the study population, ranging in volume from between 15 and 30 L (n = 148). Flasks (*kolba*) and small jars were also used by 2% and 1% respectively (n = 148). Little variation was shown amongst the type of container used for water collection and storage between rainy and dry season. All of the respondents from the household observations and informal questioning used donkeys to help transport water from the source to the household. A noticeable gender difference is also displayed in terms of water collection; 100% of respondents reported the primary domestic water collector to be a female member of the household (n = 148), however on occasions when female members weren't able to collect water for reasons unknown, other adult females (41%), the male head of household (34%) or female children (18%) would collect the water (n = 148).

3.2. Sanitation, hygiene and household environment

Just under half (47%) of the respondents confirmed they had latrine facilities from the quantitative surveys (n = 148). Out of the household included in the observations 10/12 were observed to have a latrine. All latrine facilities observed (n = 10) were unimproved according the JMP standards; the pit latrines used were without a proper slab or platform. The extent of latrine utilisation habits of households in the study area is uncertain; observations showed no visible signs of use and no odour in the facility. Of the remaining 53% survey respondents who practise open defecation in the bush areas around the community settlement, over half of them did not feel safe when defecating, noticeably more men (86%) felt unsafe than women (69%) (n = 79). The higher proportion of men feeling unsafe may be because they are likely to be further away from villages following daily or seasonal grazing routes. This means that they are less sure about the places they are defecating in terms of animal risks (e.g. snakebites) but also in terms of violence risks from neighbouring clans. Nearly all (97% of men and 90% of women) of those who didn't have a latrine, reported they would like to have one (n = 79), however when asked informally if they knew the benefits of constructing a latrine the most common answer was 'I don't know, the government told us to build it' or 'it's nice because I don't have to walk as far'.

Data on hygiene can be challenging to capture, however certain observations and informal questioning helped to develop our contextual understanding around these practices. Soap was observed in only 2/12 households, however the utilisation of the soap is uncertain as no specific handwashing facilities, such as a tippy-tap (a low-cost device that uses a small container to create a handwashing station), were observed. During the observations 10/12 households said that they 'wash their hands with soap, when they can afford to buy it'. 8/12 households self-reported positively to handwashing but couldn't specify the critical times of handwashing, yet 3/12 households self-reported to washing their hands 'before eating, after defecation, after cleaning infants, after braiding hair, after milking and after working with animals', which were key risk periods identified during the study. Every survey respondent (100%) kept goats and sheep, 91% camels, 76% cattle and 70% donkeys (n = 148). Field and household observations showed that goats were sometimes kept inside households and sheep and donkeys were kept beside it. 5/12 households were observed to have kids (baby goats) inside the living area during the time of the observation. During the observations 8/12 households had a noticeable number of flies inside the living structure and only 4/12 households were perceived 'clean' by the observer. Animal faeces, dry and fresh, was observed within 30 m of every household (12/12).

Table 2
Pastoral community WASH risk assessment analysis - water and sanitation.

	Overall Score for Pastoralists in Afar	Hazards	Risks	Seriousness of Risk	Breakdown - Difficulty of Addressing the Problem	Overall – Difficulty of Addressing the Problem
WATER						
1.1 Water Source	+	Possible pathogens present in water source.	Risk of individuals drinking contaminated water and developing waterborne illnesses,	High Risk	Technical Skill – High Cost – High Behavioural Difficulty - Low	High
1.2 Water Quantity	+	Not enough water for basic survival needs for all members of the household.	Individuals suffer from dehydration and become unable to carry out daily activities and their immune systems become weaker.	High Risk	Technical Skill – High Cost – High Behavioural Difficulty - Low	High
1.3 Water Transportation	+	Individuals spend more than 30 min walking to a water source and are tired and exhausted and struggle to carry out other daily activities.	Individuals suffer from dehydration from walking long distances in extreme heat (often more than 7 h a day), become exhausted, immune system weakens and more susceptible to infection.	High Risk	Technical Skill – High Cost – High Behavioural Difficulty - Low	High
1.4 Household Water Storage Container	++	Water is contaminated or recontaminated during storage and pathogens are present in drinking water.	Individuals are more exposed to pathogens within the household. They may drink, what is considered safe water, that has been recontaminated.	Medium Risk	Technical Skill – Low Cost – Low Behavioural Difficulty - Medium	Medium
1.5 Household Water Storage Location	++	Water is contaminated or recontaminated during storage through animal and/or human faecal pathogens present in household.	Water being stored becomes recontaminated and individuals drink what they think is safe water.	Medium Risk	Technical Skill – Low Cost – Low Behavioural Difficulty - Medium	Medium
1.6 Household Water Treatment	+	Water is not treated and because of unsafe sources, poor storage and handling, water quality deteriorates, and individuals become exposed to pathogens.	Water contains pathogens that can lead to diarrhoeal diseases and/or other illnesses.	High Risk	Technical Skill – Medium Cost – Medium Behavioural Difficulty - Medium	Medium
1.7 Water Drawing Methods	+++	Water is poured directly from storage container to drinking or cooking vessel.	Water contamination or recontamination risks are reduced due to reliable water drawing techniques.	Low Risk	Technical Skill – Low Cost – Low Behavioural Difficulty - Low	Low
SANITATION						
2.1 Latrine Access	++	Faecal pathogens not contained effectively, increasing exposure for faecal-oral transmission.	Increased faecal pathogens within environment, increased exposure leading to diarrhoeal illnesses and further to children malnutrition and stunted growth.	Medium Risk	Technical Skill – Medium Cost – Medium Behavioural Difficulty – High	High
2.2 Defecation Safety	++	Some individuals feeling unsafe when defecating, therefore open defecate closer to household, increasing community exposure to pathogens.	Individuals are forced to defecate in areas culturally unacceptable and close to domestic domain, developing higher exposure to pathogens and therefore diarrhoeal illnesses.	Medium Risk	Technical Skill – Low Cost – Low Behavioural Difficulty – High	High
2.3 Diarrhoeal Incidences	++	Some individuals suffer from diarrhoea therefore other members of households become exposed to pathogens if incidences aren't dealt with properly.	Individuals suffer from dehydration and increased pathogen exposure.	High Risk	Technical Skill – Medium Cost – Medium Behavioural Difficulty - High	High
	Overall Score for Pastoralists in Afar	Hazards	Risks	Seriousness of Risk	Breakdown - Difficulty of Addressing the Problem	Overall – Difficulty of Addressing the Problem

(continued on next page)

Table 2 (continued)

Overall Score for Pastoralists in Afar	Hazards	Risks	Seriousness of Risk	Breakdown - Difficulty of Addressing the Problem	Overall – Difficulty of Addressing the Problem
WATER					
HYGIENE					
3.1 Handwashing Facilities	+	Individuals cannot wash hands with soap at critical times, therefore increased exposure to pathogens.	High Risk	Technical Skill – Medium Cost – Low Behavioural Difficulty - High	Medium
3.2 Handwashing Timings	++	Individuals exposed to pathogens at preventable critical times.	Medium Risk	Technical Skill – Low Cost – Low Behavioural Difficulty - High	Medium
HOUSEHOLD ENVIRONMENT					
4.1 Cleanliness	++	Individuals, adults and especially children, are exposed to pathogens within their living area.	Medium Risk	Technical Skill – Low Cost – Low Behavioural Difficulty - High	Medium
4.2 Animal Presence	++	Individuals are exposed to faecal pathogens and zoonotic diseases and flies that transmit pathogens,	Medium Risk	Technical Skill – Low Cost – Low Behavioural Difficulty - High	Medium
4.3 Faecal Presence	++	Individuals are exposed to faecal pathogens and flies that transmit pathogens.	Medium Risk	Technical Skill – Medium Cost – Low Behavioural Difficulty - High	Medium

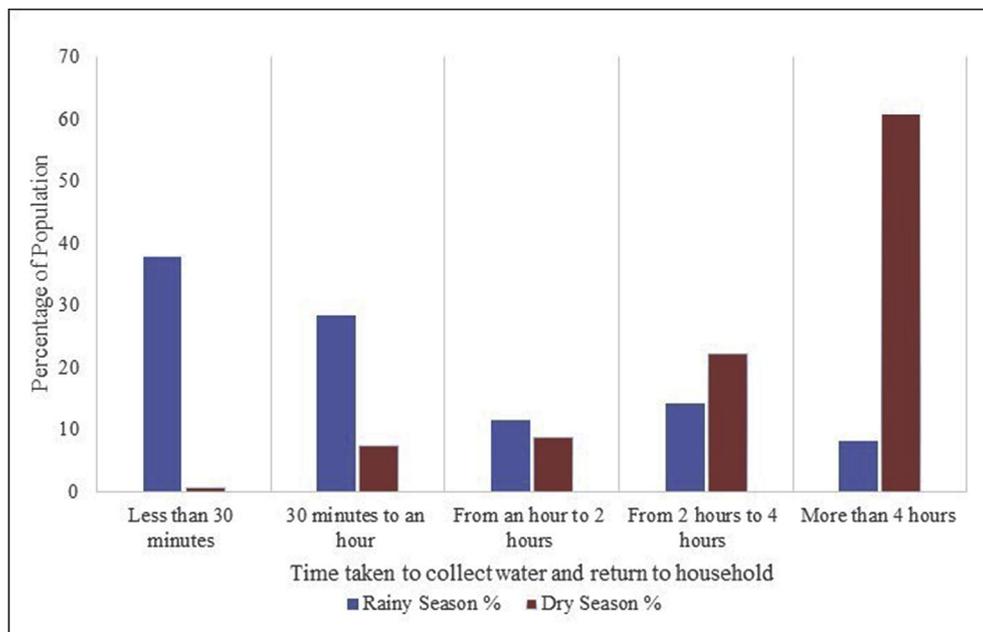


Fig. 2. Seasonal difference for water collection time.

3.3. Risk assessment of water supply

The results from the risk assessment process are summarised in Table 2 below and discussed in this section. Out of seven water supply related indicators, four were considered to have not met the target indicating a high risk of exposure to the related hazard. These were water source, water quantity, water transportation and household water treatment. In terms of water sources, surface water sources are renowned for being unfit for drinking because of their possible exposure to contamination (Davis and Lambert, 2002; Usman et al., 2016) and with 68% of the study population collecting their water from rivers and ponds for at least part of the year this was deemed a high risk area ($n = 148$). Similarly, nearly the whole study population travels for longer than 30 min to reach their water source in the dry season; a shocking 61% walk for longer than 4 h every day ($n = 148$). A systematic review of drinking water contamination between source and point-of-use carried out by Wright et al. (2004), displayed that the bacteriological quality of water significantly declines after collection, therefore this is likely to contribute to water borne infection risks as well as take a toll on overall wellbeing. Furthermore, two thirds of the population are collecting under 25 L per capita per day ($n = 148$), which is less than the recommended water quantity standard of Ethiopia's GTP II (Ministry of Water, 2015). Finally, the survey showed household water treatment is not common in these villages (87% did not treat their water in this study) but where it did reportedly occur it was in the form of boiling or simple cloth filtration ($n = 148$).

Of those four factors, the difficulty of addressing the problem was ranked as high in three of the cases with only household water treatment being considered a medium difficulty. This allocation as medium difficulty is made despite the evidence on the difficulties in promoting behavioural change to enable the consistent use of household water treatment (Hunter, 2009). However, the other issues related to water source, quantity and transport, require substantial development of infrastructure that in this water scarce region is beyond most conventional WASH project budgets. This in part, relates to the particular challenges concerning water source infrastructure development in pastoralist areas. First, quantity demands are so high because of the need to provide enough water for livestock, which drives up costs (Nasser and Belayhun, 2012). Second, even if these quantities can be supplied in such locations, pastoralists must still travel with their

animals to access new grazing land away from water points – and during this time they are often reliant on unimproved water sources both for human and animal consumption (Nasser and Belayhun, 2012). These factors connect to an even more fundamental concern that should be reflected upon when considering the development of water infrastructure in the Afar region for pastoralists. Living under some level of scarcity is a fundamental part of the socio-cultural system, and livelihoods and the way of life of pastoralists is attuned to this reality (Tilahun et al., 2016). For example, mobility is a key strategy to overcome seasonal scarcity and, more recently, there have been shifts in herd compositions towards more hardy animals such as camels to cope with growing water scarcity (Reda, 2011). We do not believe that such matters should negate a commitment to providing infrastructure in this region but such socio-cultural and livelihood factors must be considered in such efforts. These factors mean that in our assessment low technology household water treatment such as boiling or chlorination could be an appropriate solution for these populations, especially for children or during infection outbreaks, even if it is not a long-term solution.

The two other water supply areas that were evaluated to have partially met their targets were related to household water storage containers and location, whilst water drawing methods were considered to have reached their target. Safe water storage behaviour can improve the microbial quality of water, through the settling and natural die-off of pathogens, and therefore reducing pathogen load (Shaheed et al., 2014). Findings from this study in Afar highlight that the containers had small openings (spout) which have been associated with reductions in faecal contamination because of less exposure to contaminated fingers, flies and animals touching it within the house (Mintz et al., 1995). Visual observations around the cleanliness of the water storage containers were made with 10/12 containers inspected having a build-up of dirt around the spout area, and 9/12 households used containers where dirt-filled scratches were visible. Simple cleaning or disinfection of jerrycans could reduce the pathogen count, however this would involve resources such as chlorine, soap and water, which are scarce in this environment. The water pouring method carried out by pastoralists displays low risk as they pour directly from the container to the drinking vessel, yet the microbial cleanliness of the spout area (and the drinking vessel) is unknown which again, could be a cause for re-contamination. Here, we tentatively suggest that the purchasing, upkeep and use of water containers, storage locations and water drawing

methods could be another feasible intervention area within a pastoralist context so to reduce exposure to WASH related hazards.

3.4. Risk assessment of sanitation, hygiene and household environment

Across the eight potential risks areas associated with sanitation, hygiene and household environment, the risk assessment process classified one area (hand washing facilities) as completely missing the target with all other areas considered to partially meet the target (although, no areas were considered to have completely met the target). Focusing on sanitation, the survey indicated that just under half of the study population reported to have their own latrine, though latrine utilisation is uncertain. Observations showed odourless, fly-absent and insecure structures with very little faecal evidence, but this could be due to the extremely dry environment. Whilst the facilities theoretically serve as a primary barrier in the F-diagram to mitigating individual and community exposure to faecal pathogens, universal coverage and effective hygiene practices are needed to prevent risks faced by pathogen exposure in the environment (Garn et al., 2017; Jung et al., 2016). Similarly, building on the ‘herd protection’ argument, Fuller and Eisenberg (2016) emphasises that sanitation interventions must reach close to 100% coverage in order to substantially reduce risks, resulting in ‘less cumulative environmental contamination’. In this setting where animal faeces are common in the environment, we would suggest the health benefits associated with further latrine construction, even if reaching 100% coverage, may not be realised without parallel improvements in environmental hygiene. For those reasons, as well as our general comments above on the challenge of infrastructure construction in such remote and resource scarce settings, we make assessments that the difficulty of addressing sanitation coverage and related health benefits (represented by the diarrhoeal incidents column in the risk assessment) will be high. This said, community-led sanitation interventions have the potential to succeed in pastoralist settings, whereby community mobilisation and intervention entry points could be commanded through the local cultural leadership system. Pastoral communities in Afar have strong respect for seniority with elders playing a dominant and influential role in the community. The assessment process also identified safety when defecating as an important wellbeing and mental health concern. Ultimately, without improved infrastructure providing a safe place to defecate then this issue will also be hard to address.

Handwashing constitutes a secondary barrier in the F-diagram, yet it can be argued that it is the most important and vital barrier in a pastoral setting. The high levels of contact with animals, cultural traditions such as braiding hair, and household behaviour such as wiping cooking vessels clean with hands, highlight the areas of potential transmission. Observation data indicated no handwashing facilities in the study area highlighting a failure on that indicator, whilst knowledge about handwashing behaviours such as appropriate times for washing hands, was considered partial in the communities. Respondents were only able to report some of the key handwashing times when asked, including before food preparation and after defecation. However, as with the other factors in this assessment, the difficulty of addressing these issues is limited by the contextual setting and in particular, a lack of readily available water and soap for handwashing.

The final areas of the assessment were within and around the household environment. Pastoralists build their domestic structures on soil, which can act as a reservoir for faecal pathogens, and is extremely difficult to keep clean. They also live in close proximity to animals bringing with it risk of zoonotic pathogen exposure. Kids (baby goats) were observed roaming in and out of the household where children were crawling, water containers were stored, and food preparation was carried out. Exposure to faecal pathogens being brought into the domestic domain from the outside presents a high risk. Securing their kids (baby goats) inside the house to stop them from roaming in and out is likely to lower the risk slightly, but with no control over where animals

defecate, a concern is raised. Children experience long-term growth shortfalls when continuously exposed to faecal pathogens (Budge et al., 2019) and where they play on soils that harbour these pathogens, the possibility of them ingesting them, either directly or indirectly, through dust particles or transmission through fingers, is vast. These risk findings are in accordance with a systematic review investigating exposure to animal faeces and human health carried out by Penakalapati et al. (2017). In making these points, we are also aware that Headey et al. (2017) discuss that livestock ownership could have positive effects on child growth through animal-sourced food consumption. However, we do believe that livestock also present health risks associated with faecal-oral infection which are poorly understood from a research perspective and inadequately controlled for via conventional WASH programming. We also note that taking the Afar pastoralist population in our study as an example of beneficial impacts of animal-source food consumption may be negated by a lack of dietary diversity (for example – in terms of plant-based foods) which are also a significant driver of infant health (Rah et al., 2010; Sié et al., 2018). Furthermore, our study did not seek to empirically assess such matters but rather apply a broad faecal pathogen risk assessment framework and from that perspective we judge that the risks from animal faeces are of relevance.

3.5. Implications for practice

In terms of addressing the risk from animals, we believe this is an area whereby workable solutions may be found. Pastoralists are reliant on their animals but also expert in their husbandry and management. It may be possible to co-develop solutions with pastoralists to develop strategies for reducing direct human exposure, especially among infants, to animal faeces. Such thinking aligns with the multiple-use service (MUS) paradigm that argues that the provision of water in rural areas should make livelihood concerns, especially agricultural, a central consideration (Smits et al., 2010). For pastoralists, this means thinking through the provision of water for livestock. We agree here but go further to argue that WASH interventions for pastoralists should also be taking into consideration sanitary and hygiene risks from animals, as well as how water can improve livelihood productivity. In terms of specific intervention modalities, we note that the Community Led Total Sanitation (CLTS) has been proven to be an effective approach for improving the sanitation of settled communities across Asia and Africa. Within CLTS the provision of infrastructure from an implementing agency is not usually part of the intervention; a participatory process of collective behavioural triggering is used and communities develop their own facilities. Pastoral communities, with a clan-based leadership system and strong deference to such leaders, could provide favourable conditions for interventions that entail mobilisation. However, in an evaluation of the effectiveness of CLTS over five years of programming across pastoralist areas in Ethiopia, it was concluded that “people living in their programme areas are still found to live in unsatisfactory sanitation and poor hygienic conditions” (BDS-Center for Development Research, 2016). We believe recalibrating CLTS type approaches to focus on holistic, participatory WASH interventions that incorporate livestock both in terms faecal pathogen risks and livelihood productivity aspects, would be the most promising route for developing bespoke WASH programmes in this area.

3.6. Limitations

We are aware that the interpretation of findings from a study reliant on survey and observational data, processed via a qualitative risk assessment framework, are always implied, and the identified public health risks cannot be verified by appropriate microbiological or other technical techniques. We also note that the imbalance of data between surveys and observational methods that feed into the risk assessment reduce the ability to conduct specific and comparative analysis of sub-groups, and therefore the results are presented at a generalised level for

the three villages in which we worked. Extrapolating these findings as representative of the Afar pastoralists and, especially, pastoralist populations more generally, is also limited by the number of villages in this study. In acknowledging these limitations, we note the paucity of work focused on the specific WASH related risks of pastoralists and the related logistical challenges of conducting fieldwork in such areas, which can often be many hours walk from the closest roads, and still believe this paper represents a useful contribution in this area. We intend this paper to be read both as presenting useful data and contextual information on pastoralist WASH risks as well as a call-for-arms for tailored and holistic WASH interventions for this population.

4. Conclusion

As the global sector seeks to respond to the Sustainable Development Goals to leave no-one behind and move towards universal WASH, we still face the challenge of “last mile” access (e.g. reaching the most marginalised and difficult to serve groups). The sector – including policy-makers, practitioners and researchers – therefore need to develop the strategies, tools and understanding needed to extend services to these groups. This research provides insight into the water handling, sanitation and hygiene practices of pastoralists in Afar and makes suggestions about the type of interventions that are likely to respond to the needs of this group and reduce the faecal-oral pathogen transmission. The implications for policy-makers is that contextualisation of programming will be critical in ensuring successful and sustainable interventions. They should therefore be prepared to create an enabling environment that allows this. The aforementioned calls for integrated WASH programmes that address environmental health and livestock productivity, which requires institutional structures and funding mechanisms that can be leveraged to deliver holistic initiatives. It may also mean accepting smaller-steps in the development of one area (e.g. improved environmental hygiene via new animal husbandry practices) rather than judging success purely by the infrastructure-orientated targets that dominate the WASH sector.

Similarly, practitioners need to go beyond conventional approaches and seek to reimagine what interventions could look like for pastoralists. This requires some careful experimentation, of which we would suggest two starting points for this. First, the role of livestock both as a livelihood enhancement strategy but also as part of improved sanitary and hygiene conditions and, second, that interventions should be co-produced in partnership with pastoralist communities as they are experts in surviving and thriving in harsh and infrastructure-poor environments. Researchers also have a role to help further build the evidence base on the contextual faecal-oral contamination pathways that need to be interrupted and provide assessments on the effectiveness of new approaches. In Afar, such work needs to be accompanied by careful consideration of the pastoralist way of life and, as such, social, cultural and livelihood appraisals will be critical in helping practitioners contextualise interventions in partnership with communities themselves. Developing the new strategies, tools and understanding needed to improve WASH in these settings will require challenging and multi-level action but it is necessary to help serve such populations.

Acknowledgements

This research has been supported by the Economic and Social Research Council and Department for International Development through the Development Frontiers Research Fund (Grant: ES/R001049/1). The research could not have been carried out without the support of local project facilitators, Friendship Support Association (FSA), an organisation focusing on education, water, health and livelihoods in the Afar. The authors would also like to acknowledge the patience and time of research participants for answering questions and allowing us to learn about their way of life and household practices. The data used in this article is described in CORD at <https://10.17862/cranfield.rd.9332279>; it is subject to an embargo, and will be available from 7 August 2020. The protocols for data collection and analysis are available via the supplementary data section.

[cranfield.rd.9332279](https://10.17862/cranfield.rd.9332279); it is subject to an embargo, and will be available from 7 August 2020. The protocols for data collection and analysis are available via the supplementary data section.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ijheh.2019.08.001>.

References

- Afar National Regional State, 2010. Afar National Regional State Programme of Plan on Adaptation to Climate Change. (Addis Ababa, Ethiopia).
- BDS-Center for Development Research, 2016. Outcome Evaluation of Community Led Total Sanitation and Hygiene: Ethiopia 2012-15. BDS-Centre for Development Research, Addis Ababa.
- Budge, S., Parker, A.H., Hutchings, P.T., Garbutt, C., 2019. ‘Environmental Enteric Dysfunction and Child Stunting’, Nutrition Reviews, Special Ar(NUY068). Available at: <https://doi.org/10.1093/nutrit/nyy068>, Accessed date: 19 February 2019.
- Clasen, T., Boisson, S., Routray, P., Torondel, B., Bell, M., Cumming, O., Ensink, J., Freeman, M., Jenkins, M., Odagiri, M., Ray, S., Sinha, A., Suar, M., Schmidt, W.-P., 2014. Effectiveness of a rural sanitation programme on diarrhoea, soil-transmitted helminth infection, and child malnutrition in Odisha, India: a cluster-randomised trial. *Lancet Glob. Health* 2, 645–653.
- Curtis, V., Cairncross, S., Yonli, R., 2000. Domestic hygiene and diarrhoea - pinpointing the problem. *Trop. Med. Int. Health* 5 (1), 22–32.
- Davis, J., Lambert, R., 2002. In: RedR (Ed.), *Engineering in Emergencies*, second ed. Rugby Practical Action Publishing.
- Fuller, J.A., Eisenberg, J.N.S., 2016. Herd protection from drinking water, sanitation, and hygiene interventions. *Am. J. Trop. Med. Hyg.* 95 (5), 1201–1210 The American Society of Tropical Medicine and Hygiene.
- Garn, J.V., Sclar, G.D., Freeman, M.C., Penakalapati, G., Alexander, K.T., Brooks, P., Rehfuess, E.A., Boisson, S., Medlicott, K.O., Clasen, T.F., 2017. The impact of sanitation interventions on latrine coverage and latrine use: a systematic review and meta-analysis. *Int. J. Hyg Environ. Health* 220 (2), 329–340 Elsevier GmbH.
- Headey, D., Nguyen, P., Kim, S., Rawat, R., Ruel, M., Menon, P., 2017. Is exposure to animal feces harmful to child nutrition and health outcomes? A multicountry observational analysis. *Am. J. Trop. Med. Hyg.* 96 (4), 961–969 The American Society of Tropical Medicine and Hygiene.
- Hunter, P.R., 2009. Household water treatment in developing countries: comparing different intervention types using meta-regression. *Environ. Sci. Technol.* 43 (23), 8991–8997.
- Jung, S., Doh, Y.-A., Bizuneh, D.B., Beyene, H., Seong, J., Kwon, H., Kim, Y., Habteyes, G.N., Tefera, Y., Cha, S., 2016. 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. *Trials* 17 (1), 204 BioMed Central.
- Kassie, G.G., Hayelom, D.H., 2017. Assessment of water handling and sanitation practices among rural communities of farta Woreda. *Northwest Ethiop.* 5 (5), 119–124.
- Keusch, G.T., Rosenberg, I.H., Denno, D.M., Duggan, C., Guerrant, R.L., Lavery, J.V., Tarr, P.I., Ward, H.D., Black, R.E., Nataro, J.P., Ryan, E.T., Bhutta, Z.A., Coovadia, H., Lima, A., Ramakrishna, B., Zaidi, A.K.M., Hay Burgess, D.C., Brewer, T., 2013. Implications of acquired environmental enteric dysfunction for growth and stunting in infants and children living in low-and middle-income countries. *Food Nutr. Bull.* 34 (3), 357–364.
- Luby, S.P., Rahman, M., Arnold, B.F., Unicomb, L., Ashraf, S., Winch, P.J., Stewart, C.P., Begum, F., Hussain, F., Benjamin-Chung, J., Leontsini, E., Naser, A.M., Parvez, S.M., Hubbard, A.E., Lin, A., Nizame, F.A., Jannat, K., Ercumen, A., Ram, P.K., Das, K.K., Abedin, J., Clasen, T.F., Dewey, K.G., Fernald, L.C., Null, C., Ahmed, T., Colford, J.M., 2018. Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural Bangladesh: a cluster randomised controlled trial. *Lancet Glob. Health* 6 (3), e302–e315. [https://doi.org/10.1016/S2214-109X\(17\)30490-4](https://doi.org/10.1016/S2214-109X(17)30490-4).
- Ministry of Water, I. and E., 2015. Second Growth and Transformation National Plan for the Water Supply and Sanitation Sub-group. (Addis Ababa, Ethiopia).
- Mintz, E., Reiff, E., Tauxe, E., 1995. Safe water treatment and storage in the home: a practical new strategy to prevent waterborne diseases. *J. Am. Med. Assoc.* 948–953 Assn 273.
- Mosites, E., Dawson-Hahn, E., Walsom, J., Rowhani-Rahbar, A., Neuhaus, M.L., 2017. Piecing together the stunting puzzle: a framework for attributable factors of child stunting. *Paediatr. Int. Child Health* (3), 158–165. <https://doi.org/10.1080/20469047.2016.1230952>. mWater (no date) mWater. <https://www.mwater.co/>.
- Nasser, M., Belayhun, M., 2012. Water Development in Ethiopia's Pastoral Areas: A synthesis of existing knowledge and experience. Save the Children, USA. https://www.usaid.gov/sites/default/files/documents/1860/Water.Development.in.Pastoral.Areas.of.Ethiopia_0.pdf.
- Ngure, F.M., Reid, B.M., Humphrey, J.H., Mbuya, M.N., Pelto, G., Stoltzfus, R.J., 2014. Water, sanitation, and hygiene (WASH), environmental enteropathy, nutrition, and early child development: making the links. *Ann. N. Y. Acad. Sci.* 1308 (1), 118–128.
- Null, C., Stewart, C.P., Pickering, A.J., Dentz, H.N., Arnold, B.F., Arnold, C.D., Benjamin-Chung, J., Clasen, T., Dewey, K.G., Fernald, L.C.H., Hubbard, A.E., Kariger, P., Lin, A., Luby, S.P., Mertens, A., Njenga, S.M., Nyambane, G., Ram, P.K., Colford, J.M., 2018. ‘Effects of water quality, sanitation, handwashing, and nutritional interventions on

- diarrhoea and child growth in rural Kenya: a cluster-randomised controlled trial.’, the *Lancet. Glob. Health* 6 (3), e316–e329. [https://doi.org/10.1016/S2214-109X\(18\)30005-6](https://doi.org/10.1016/S2214-109X(18)30005-6). Elsevier.
- Penakalapati, G., Swarthout, J., Delahoy, M.J., McAliley, L., Wodnik, B., Levy, K., Freeman, M.C., 2017. Exposure to animal feces and human health: a systematic review and proposed research priorities. *Environ. Sci. Technol.* 51 (20), 11537–11552.
- Prüss-Ustün, A., Bartram, J., Clasen, T., Colford, J.M., Cumming, O., Curtis, V., Bonjour, S., Dangour, A.D., De France, J., Fewtrell, L., Freeman, M.C., Gordon, B., Hunter, P.R., Johnston, R.B., Mathers, C., Mäusezahl, D., Medlicott, K., Neira, M., Stocks, M., Wolf, J., Cairncross, S., 2014. Burden of disease from inadequate water, sanitation and hygiene in low- and middle-income settings: a retrospective analysis of data from 145 countries. *Trop. Med. Int. Health* 19 (8), 894–905.
- Rah, J.H., Akhter, N., Semba, R.D., Pee, S. de, Bloem, M.W., Campbell, A.A., Moench-Pfanner, R., Sun, K., Badham, J., Kraemer, K., 2010. Low dietary diversity is a predictor of child stunting in rural Bangladesh. *Eur. J. Clin. Nutr.* 64 (12), 1393–1398. [10.1038/ejcn.2010.171](https://doi.org/10.1038/ejcn.2010.171).
- Reda, T.K., 2011. Social organisations and cultural institutions of the Afar of Northern Ethiopia. *Int. J. Sociol. Anthropol.* 3 (11), 423–429.
- Shaheed, A., Orgill, J., Montgomery, M.A., Jeuland, M.A., Brown, J., 2014. Why “improved” water sources are not always safe. *Bull. World Health Organ.* 92 (4), 283–289 World Health Organization.
- Síé, A., Tapsoba, C., Dah, C., Ouermi, L., Zabre, P., Bärnighausen, T., Arzika, A.M., Lebas, E., Snyder, B.M., Moe, C., Keenan, J.D., Oldenburg, C.E., 2018. Dietary diversity and nutritional status among children in rural Burkina Faso. *Int. Health* 10 (3), 157–162.
- Smits, S., van Koppen, B., Moriarty, P., Butterworth, J., 2010. Multiple-use services as an alternative to rural water supply services: a characterisation of the approach. *Water Altern. (WaA)* 3 (1), 102–121.
- Tilahun, M., Angassa, A., Abebe, A., Mengistu, A., 2016. Perception and attitude of pastoralists on the use and conservation of rangeland resources in Afar Region, Ethiopia. *Ecol. Process.* 5 (1), 18. <https://doi.org/10.1186/s13717-016-0062-4>.
- Usman, M., Gerber, N., Pangaribowo, E., 2016. Determinants of Household Drinking Water Quality in Rural Ethiopia. SSRN Discussion Paper, pp. 220.
- Watanabe, K., Petri, W.A., 2016. Environmental enteropathy: elusive but significant subclinical abnormalities in developing countries. *EBioMedicine* 10, 25–32. <https://doi.org/10.1016/j.ebiom.2016.07.030>.
- WHO, 2017. Diarrhoeal Disease Key Facts.
- WHO, 2011. Guidelines for Water Quality, fourth ed. World Health Organisation, Geneva.
- WHO, 2013. Household Water Treatment and Safe Storage: Manual for the Participant Geneva.
- WHO, UNICEF, 2017a. Progress on Drinking Water, Sanitation and Hygiene, Geneva.
- WHO, UNICEF, 2017b. Water and Sanitation for Health Facility Improvement Tool (WASH FIT): A Practical Guide for Improving Quality of Care through Water, Sanitation and Hygiene in Health Care Facilities. WHO, Geneva.
- Wright, J., Gundry, S., Conroy, R., 2004. Household drinking water in developing countries: a systematic review of microbiological contamination between source and point-of-use. *Trop. Med. Int. Health* 9 (1), 106–117.