Animal Handling Practice Among Rural Households in Northwest Ethiopia Increases the Risk of Childhood Diarrhea and Exposure to Pathogens From Animal Sources

Environmental Health Insights
Volume 18: 1–11
© The Author(s) 2024
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/11786302241245057

Zemichael Gizaw[1,2,3], Alemayehu Worku Yalew[4], Bikes Destaw Bitew[1], Jiyoung Lee[5,6] and Michael Bisesi[5]

[1]Department of Environmental and Occupational Health and Safety, Institute of Public Health, College of Medicine and Health Sciences, University of Gondar, Gondar, Ethiopia. [2]Addis Continental Institute of Public Health, Addis Ababa, Ethiopia. [3]Global One Health Initiative (GOHi), the Ohio State University, Columbus, OH, USA. [4]School of Public Health, Addis Ababa University, Addis Ababa, Ethiopia. [5]Division of Environmental Health Sciences, College of Public Health, The Ohio State University, Columbus, OH, USA. [6]Department of Food Science and Technology, the Ohio State University, Columbus, OH, USA.

ABSTRACT

BACKGROUND: In Ethiopia, domestic animals and their feces are not properly contained. However, the risk of exposure to zoonotic pathogens is not well documented. This study was conducted to assess animal handling practices and the risk of childhood diarrhea among rural households in northwest Ethiopia.

METHODS: This study was done among 403 randomly selected households. Information on animal handling was collected using a questionnaire and spot-check observation. The occurrence of childhood diarrhea in 14 days prior to the survey was assessed based on the reports of female head of households. Multivariable binary logistic regression analysis was performed to identify the association between animal handling practices and childhood diarrhea.

RESULTS: All the female head of households had contact with animal feces when preparing fuel disks and plastering the house components with animal dung. Domestic animals shared a corral within the living space of the humans in 20% of the households. Animals entered the human living quarters and accessed foods in 32% of the households. Moreover, 24% of the children aged 24 to 59 months had diarrhea in a 2-week period prior to the survey. Childhood diarrhea was associated with domestic animals sharing the same house as humans (AOR: 3.3, 95% CI: 1.3, 8.6), presence of animal excreta in child playing areas (AOR: 2.4, 95% CI: 1.2, 4.6), contact of domestic animals with stored foods (AOR: 3.5, 95% CI: 2.0, 5.9), trapped dirt under fingernails of female heads (AOR: 3.7, 95% CI: 1.9, 7.5), open defecation (AOR: 3.24, 95% CI: 1.8, 5.9), and unprotected sources (AOR: 4.2, 95% CI: 1.1, 15.3).

CONCLUSION: Domestic animals and their excreta are not hygienically contained in the area. Animal handling practices including their excreta and the hygiene behavior of female head of households (eg, handwashing and food handling practices) should be improved to prevent childhood diarrhea.

KEYWORDS: Livestock husbandry practice, animal excreta, fecal contamination, childhood diarrhea, rural households, northwest Ethiopia

RECEIVED: March 7, 2024. **ACCEPTED:** March 18, 2024.

TYPE: Original Research

FUNDING: The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study is funded by One Health Eastern Africa Research Training (OHEART) programe at the Ohio State University, Global One Health Initiative (GOHi) through National Institutes of Health (NIH) Fogarty International Center (grant number TW008650) and the University of Gondar (grand number R/T/T/C/Eng./300/08/2019).

DECLARATION OF CONFLICTING INTERESTS: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

CORRESPONDING AUTHOR: Zemichael Gizaw, Department of Environmental and Occupational Health and Safety, Institute of Public Health, College of Medicine and Health Sciences, University of Gondar, P.O.Box 196, Gondar, Ethiopia. Email: zemichael12@gmail.com

Introduction

The livelihoods of rural communities in low-income countries largely rely on livestock.[1,2] About 1.3 billion poor people all over the world rely on livestock for their livelihoods and globally, livestock contributes 40% to the agricultural gross domestic product.[3] Food supply and family nutrition, income generation, soil fertility, livelihoods, transportation, and agricultural production are among the benefits of livestock contributions to rural communities.[3] However, livestock rearing has critical public health problems, for instance, about 60% of all known infectious agents and 75% of emerging human pathogens are zoonotic.[4] Moreover, zoonotic diseases are responsible for about one billion cases of illness and millions of deaths every year.[5] The burden of zoonotic infections is disproportionately high in Africa. In the continent, there has been a 63% increase in the number of zoonotic outbreaks in the region in the decade from 2012 to 2022 compared to 2001 to 2011.[6] The increase in zoonotic cases may be due to several reasons. Africa has the world's fastest-growing population and there is a growing demand for food derived from animals including meat, poultry, eggs, and milk. The population growth is also leading to rising urbanization and encroachment on the habitats of wildlife.[6,7]

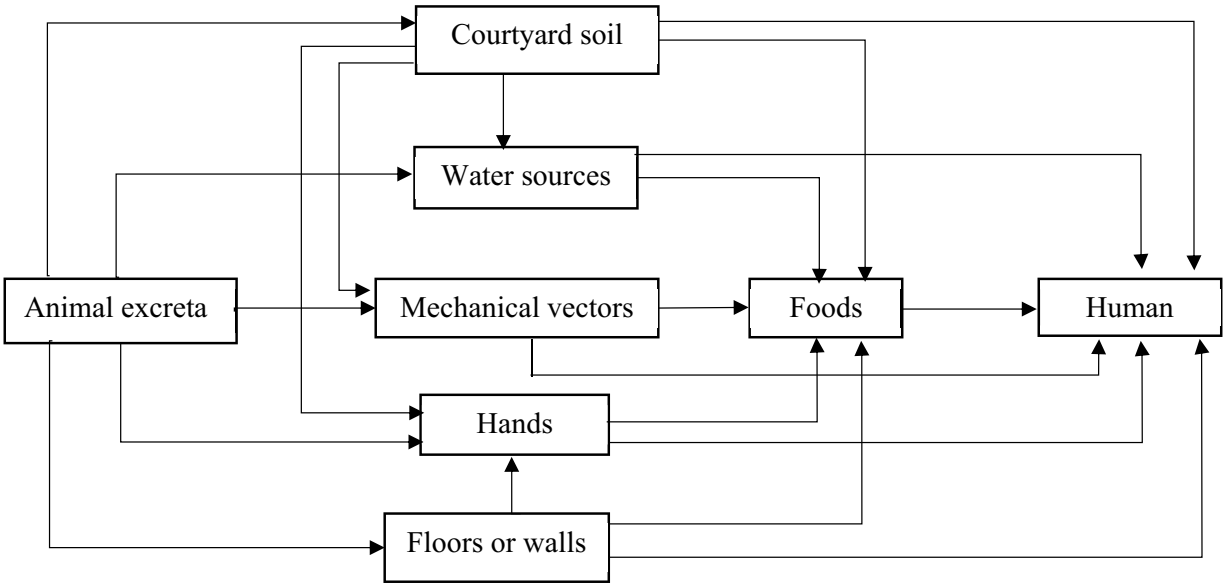

Figure 1. Exposure pathways of rural communities to animal excreta (adapted from the classic "F-diagram"[21]). Mechanical vectors are insects such as flies that carry pathogenic microorganisms and transmit them through physical contact without supporting their development.

Moreover, fecal contamination of the living environment from human and animal sources also poses a significant risk of transmission of zoonotic pathogens in human. The living environment is defined here as an assembly of the natural and built environment which is offered to the inhabitants of the place who perform various kinds of social, cultural, religious, and economic activities.[8] The predominant risk factor for human diarrhea is environmental contamination from human excreta.[9,10] However, zoonotic infections can also cause diarrhea in humans and can be transferred through animal feces.[11] Many pathogens, for example, *Campylobacter*, non-typhoidal *Salmonella* (NTS), *Cryptosporidium*, and *Toxoplasma gondii* substantially contribute to the global burden of diarrheal disease in humans through their spread in animal feces in the domestic environment.[12] Combined, these pathogens cause close to one million deaths annually.[12] Similarly, zoonotic illnesses are prevalent in northern Ethiopia. For instance, Menghistu et al reported that 53 614 (4.2%) of human cases out of 1 273 145 observed cases in the northern parts of the country were zoonoses.[13] This could be due to inadequate hygiene and sanitation conditions and poor living quality due to climate change-driven poverty and civil war in the region.[14,15]

Rural communities can be exposed to pathogens from poorly managed animal feces.[12,16] Poor animal feces disposal leads to fecal-oral transmission of zoonotic pathogens. Fecal–oral transmission is primarily occurred indirect exposure, that is, through contaminated foods and water. However, it can also operate through direct contact with feces or contaminated body parts, such as through contaminated hands[16-20] as illustrated in Figure 1 which is adapted from the classic "F-diagram."[21]

Hands play a significant role in the fecal-oral transmission of diseases[22] and hand hygiene can reduce the risk of infection transmission.[23,24] Evidence indicates that the hands, along with contact with food and other environmental surfaces, cause 60% of the spread of gastrointestinal infections and are associated with up to 50% of respiratory tract infections.[25] Moreover, handwashing with soap reduces gastrointestinal and respiratory tract infections by up to 50% to 60%.[25] Education about handwashing in the community reduces the number of people suffering from diarrhea by 23% to 40%[24,26,27] and respiratory illnesses by 16% to 21%.[24,28] However, rural communities in the study area have poor knowledge about the importance of hand hygiene and have poor awareness of effective hand hygiene procedures. For instance, a randomized controlled trial study conducted in a rural setting of northwest Ethiopia reported that 27% and 24% of women in the intervention and control groups, respectively, did not think that they always have to wash hands after visiting the toilet and 37% and 36% women in the intervention and control groups, respectively, believed that they only need to wash hands with soap when their hands are heavily dirty.[29] Another study in a rural setting of northwest Ethiopia also reported that only 65 (18%) of women thoroughly rubbed all parts of their hands for at least 20 seconds and 44 (12%) of the women wiped their hands on their cloth to dry.[30]

It is therefore important to investigate risky behaviors of humans that lead to exposure to zoonotic agents in rural settings. This study was conducted to assess animal handling practice and its association with the risk of childhood diarrhea among rural households in northwest Ethiopia.

Methods

Study design and setting

A community-based cross-sectional study was conducted in rural settings of the east Dembiya district in May 2021. East

Dembiya district is one of the 13 districts in the central Gondar zone, the Amhara national regional state, Ethiopia. The district had a total population of 210 761 of whom 192 020 (91%) and 18 741(9%) were rural and urban residents, respectively.[31] The district is densely populated with an average of 277 inhabitants per km^2 in 2022.[32] In the district, large ruminants are the dominant livestock population followed by small ruminants and equines. The overall cattle population in the district is 166 046; sheep (8886); goats (5427); donkeys (10 717); and mules (805).[33] The district had 27% and 55% coverage for clean water and traditional pit latrines, respectively.[34]

Sample size determination and sampling procedures

The sample size was calculated using single population proportion formula with the following assumptions: proportion of rural households who properly contained domestic animals including their excreta (p) =50% since there was no similar study in the area, level of significance (α) =5%, 95% confidence interval (standard normal probability), z: the standard normal tabulated value, and minimum detectable effect (d) =5%. The final sample size was 403 after considering a non-response rate of 5%. All households that have livestock and children under the age of 5 years in the rural kebeles (the lowest administrative unit in Ethiopia) in the district were considered for sampling. First, we chose 6 rural kebeles at random out of 28 kebeles using a simple random sampling technique. We then selected 403 households using a systematic random sampling technique. We began collecting data in households located on the right side of local administrators' offices. Assuming that the average number of households in each rural kebele is 200,[35,36] a sampling interval (K = 3) was calculated by dividing 200 by the kebele's predetermined sample size (n = 67). Following that, a number between 1 and the sampling interval was chosen at random using the lottery method, which is known as the random start, and was used as the first number included in the sample. Then, after the first random start, every third household was sampled until the desired sample size for each kebele was reached. The sampling interval was corrected accordingly based on the presence of livestock, children under the age of 5 years, and female head of households.

Data collection tools and procedures

We used a structured and pretested questionnaire and spot-check observations to collect data. Questionnaire and observation checklists were prepared based on a review of relevant literature.[16,37-39] The questionnaire was first prepared in English language and translated to the local Amharic language and back-translated into English to check consistency. The questionnaire was organized into 5 parts: (i) socio-demographic characteristics of female head of households and children, (ii) livestock ownership, (iii) animal handling and animal waste management practice, (iv) perception of animal excreta, (v) water sources, hand hygiene and defecation practice, and (vi) childhood diarrhea. Field data collectors, who were environmental health professionals interviewed female head of households about their handling practices of animals including animal excreta and observed the presence of animal excreta in the living environment and child playing areas. Female head of households were interviewed because they are responsible for childcare, food preparation, fuel disk preparation, cleaning of animal barns, and plastering of the house components in the area. Field data collectors looked at the hands of female head of households and asked the respondents to identify the area where children usually played.

Measurement of variables

In this study, we analyzed the association between childhood diarrhea and animal handling practices in rural households in northwest Ethiopia. Childhood diarrheal disease was defined as having 3 or more loose or watery stools within a 24-hour period.[40] A two-week period of diarrheal disease in children[41] was determined based on the response of female head of households. Animal handling practice, including handling of animal excreta, was assessed using the following questions: (i) where are domestic animals kept during day and night times? (ii) is there animal excreta in the courtyard or other open places where children spend most of their time playing? (iii) how do households manage animal excreta? (iv) do domestic animals enter to human living quarters and access prepared and stored foods? (v) do female head of households prepare fuel disks, plaster the house component, and clean animal barns with bare hands? and (vi) do female head of households wash their hands with soap or other rubbing agents after preparing fuel disks, plastering the house component, and cleaning animal barns? A description of the variables used in the study is given in Table 1.

Data processing and analysis

We used STATA version 14[45] to analyze the data. Descriptive statistics such as frequency and percentages were used to analyze data. Data were presented using frequency tables and a bar chart. We also used pictures or photos to visualize animal handling practices including their excreta. Multivariable binary logistic regression analysis was performed to identify the association between animal handling practices and childhood diarrhea. All the relevant predictors included in the questionnaire were entered to the multivariable binary logistic regression model regardless of their bivariate *P*-value because selecting candidate variable for the adjusted models based on their univariable *P*-value could lead to incorrect exclusion of potential confounders and hence led to inadequate adjustment for confounding.[46,47] Handling practice of domestic animals, animal excreta in child playing areas, access of animal to the stored food, hand washing practice of female head of

Table 1. Description of variables used in the study.

VARIABLES	DEFINITION
Livestock ownership	Owning one or more of the following: Cattle (cows or oxen), Ovine (sheep or goats), Equine (horses, mules, or donkeys), Pets (dogs or cats), or Chicken.
Animal handling	
Properly contained	Containment of animals (e.g., containing them in a separately constructed barn from the main building) to protect fecal contamination of the living environment.
Improperly contained	Containing animals in a way that causes fecal contamination of the living environment (e.g., containing in the open field, in a corral within the living space of the humans, or in a barn constructed attached with the main building).
Handling of animal excreta	
Hygienically handled	Handling of animal excreta in a way that prevents humans and the living environment from fecal contaminations such as hygienically collect animal feces to use for composting or biogas production.
Unhygienically handled	Handling of animal excreta in a way that causes fecal contamination of humans and the living environment, e.g., discriminate disposal of animal excreta in the domestic environment and touching animal excreta with bare hands to plaster the house component or to prepare fuel disks.
Handwashing	
Effective handwashing	Washing hands with water and rubbing agents (such as soap, ash, or leaf) after touching animal excreta using hand washing facilities that can prevent cross-contamination of hands during washing such as "tippy tap" (Figure 7B).
Ineffective	Not washing hands or washing hands with water alone after touching animal excreta using receptacles that cross-contaminate hands during washing or pouring water (Figure 7A).
Defecation practice	
Open field	Practice of defecating in open fields, forests, bushes, waterways, and open trenches without any proper disposal of human excreta.
Latrine use	Disposing human excreta using any type of latrine such as pit latrine, ventilated improved (VIP) latrine, borehole *latrine, and* trench latrine.
Fecal contamination of living environment	Presence of fecal matters in the domestic environment or child playing areas.
Drinking water sources	
Ground water	Water from an aquifer such as bored wells, dug wells, driven wells, and drilled wells.
Surface water	*Water from* rivers, streams, reservoirs, springs, and ponds.
Drinking water sources	
Protected	Water sources (such as protected well, protected spring, protected rain catchment, and tap water) which are protected from flood, animal access, and wind.[42]
Unprotected	Water sources (e.g., unprotected well, unprotected spring, and unprotected rain catchment) which are not protected from animal access, flooding, and wind.[42]
Volume of water	
Limited access	Quantity collected often below 20 l per capita per day (l/c/d) from sources located more than1k m distance.[43] 20 l/c/d is the minimum quantity of safe water required to maintain minimum levels of health and hygiene.[44]
Basic access	Quantity collected above 20 l/c/d from sources within 1 km distance.[43]
Access of animal to the cooked food	Conditions where domestic animals and pets (especially chicken, dogs, or cats) gain access to cooked foods including food utensils (Figure 2A). This condition plays a significant role for fecal contamination of foods in rural settings.
Perception of female head of households about the health effects of animal excreta	The state of becoming aware of the health effects of animal excreta, which is assessed by this question: Do you believe that animal excreta contain disease-causing pathogens? [Answer options: Yes, No, and I don't know].

Table 2. Demographic characteristics of study participants (n = 372) in a rural setting of northwest Ethiopia, May 2021.

VARIABLES	FREQUENCY	PERCENT
Age of female head of households in year		
20-25	74	20
26-30	128	34
31-35	64	17
36-40	82	22
41-45	24	7
Sex of children		
Male	192	52
Female	180	48
Age of children in month		
24-36	92	25
37-48	122	33
49-59	158	42
Education status of female head of households		
No formal education	165	44
Attend formal education	207	56

households after touching animals and their excreta were the exposure variables of interest entered into the multivariable model. Moreover, covariates like education status of female head of households, drinking water sources, and defecation practices were added to the model to control their confounding effect. In the adjusted model, statistically significant associations were declared based on the adjusted odds ratio (AOR) with the corresponding 95% confidence interval and *P*-value < .05. Model fitness was checked using the Hosmer–Lemeshow model fitness test.

Results

Demographic characteristics of study participants

Data were collected from 372 out of 403 sampled households with children under the age of 5 years and owned livestock. We did not collect data from 31(12%) of the households because female heads were not available at the time of data collection. The age of female head of households included in the current study ranged from 20 to 45 years, with a mean (± SD) age of 31.7 (± 6.4) years. One hundred twenty-eight (34%) of the female head of households were between the ages of 26 and 30 years. One hundred and sixty-five (44%) of the female head of households did not attend formal education. Moreover, 192 (52%) of the children in this study were male. The age of children ranged from 24 to 59 months, with a mean (± SD) age of 42 (± 12.5) months. One hundred fifty-eight (43%) of the children were aged between 48 and 59 months (Table 2).

Livestock ownership and sanitation conditions of households

Two hundred and sixty-two (70%) of the households have cattle, 177 (48%) have ovine, 111 (30%) have equine, 358 (96%) have chickens, and 118 (32%) have pets. One hundred ninety-six (53%) of the households collected drinking water from unprotected sources (rivers, unprotected springs, or unprotected wells). Vast majority, 299 (80%) of the households collected less than 20 l/c/d of water. About two-third, 242 (65%) of the households defecated in the open field. We observed animal excreta in child play areas in 272 (73%) of the households and animals entered the human living quarters through open doors and windows to look for food in 118 (32%) of the households (Table 3 and Figure 2), through which fecal contamination of foods and food utensils occurs in the study area.

Animal handling practice

In the current study, all the households kept animals openly in the yard and public open spaces in the daytime, as shown in Figure 3. Nearly one-fifth, 74 (20%) of the households kept animals in a corral within the living space of the humans at night, 254 (68%) of the households kept animals in a barn attached to the main building, and 44 (12%) kept animals in a separately constructed barn (Figure 3). The primary reported reason to keep animals in a corral within the living space of the humans at night is fear of robberies. Thieves could steal the animals unless the owners kept them attentively in secure places.

Animal excreta handling practice

In the current study, we interviewed female head of households about their perception on the health effects of animal excreta. One-third (33%) of the female head of households did not perceive that animal excreta contains infectious agents. As illustrated in Figures 4 and 5, all the female head of households prepared fuel disks from animal dung and plastered the housing component, such as floors and walls by animal dungs with bare hands. All the female head of households who prepared fuel disks and plastered the house component with animal dung reported that they usually washed their hands after they cleaned animal barns, plastered floors/walls, and prepared fuel disks. However, one-third, 130 (35%) of them reported that they used soap to wash their hands (Figure 6) and we observed visible dirt under the fingernails among 253 (68%) of the female head of households after washing. In the area, all the households used local receptacles or "tippy tap" to wash hands (Figure 7).

Table 3. Livestock ownership and sanitation conditions of households (n = 372) in a rural setting of northwest Ethiopia, May 2021.

VARIABLES	FREQUENCY	PERCENT
Defecation practice of household members		
Open field	242	65
Traditional pit latrine	130	35
Drinking water sources		
Ground water	283	76
Surface water	89	24
Status of water sources		
Protected	176	47
Unprotected	196	53
Volume of water collected		
< 20 l/c/d	299	80
⩾ 20 l/c/d	73	20
Livestock ownership		
Cattle*	262	70
Ovine**	177	48
Equine***	111	30
Chicken	358	96
Pets****	118	32
Stored foods are accessible for animals		
Yes	118	32
No	254	68
Animal excreta in child playing areas		
Yes	272	73
No	100	27

*cows/oxen, **sheep/goats, ***horses/mules/donkeys, ****dogs/cats, l/c/d: liters per capita per day.

Association between animal handling practices and childhood diarrhea

In the current study, 90 (24%) (95% CI: 20, 29%) of the children aged 24 to 59 months had diarrhea in a 2-week period prior to the survey. Childhood diarrhea in the study area was associated with how the households handle domestic animals and their excreta. Children in households where domestic animals share the same house with humans had 3.3 times more odds of diarrhea compared with children in households where domestic animals are kept outside the main building (AOR: 3.3, 95% CI: 1.3, 8.6, *P*: .029). The odds of childhood diarrhea was 2.4 times higher in households where animal excreta was observed in child playing areas compared with their counterparts (AOR: 2.4, 95% CI: 1.2, 4.6, *P*: .007). Moreover, the odds of childhood diarrhea was 3.5 times higher in households where domestic animals entered human living quarters and accessed prepared and stored foods (AOR: 3.5, 95% CI: 2.0, 5.9, *P*: .000). Hand hygiene of female head of households, for example, trapped dirt under fingernails was significantly associated with childhood diarrhea in the area (AOR: 3.7, 95% CI: 1.9, 7.5, *P*: .000). Drinking water sources and defecation practices were also significantly associated with childhood diarrheal disease in the study area. The prevalence of childhood diarrhea was higher in households who collected drinking water from unprotected sources (AOR: 4.2, 95% CI: 1.1, 15.3, *P*: .020) and defecated in open fields (AOR: 3.24, 95% CI: 1.8, 5.9, *P*: .000) compared with their counterparts (Table 4).

Discussion

This study was conducted to assess animal handling practices including their excreta and its association with the risk of infections in a rural setting of the east Dembiya district and we found that the way rural households handle animals, and their excreta increases the risk of exposure to pathogens from animal sources. In the area, domestic animals and their feces are not properly contained or separated from domestic environments. In the daytime, all the households kept animals in the yard and public open places, and in the nighttime significant proportion of households kept animals in a corral within the living space of the humans and/or in a barn attached to the main buildings. This animal husbandry and keeping practice could result in contact of rural households with animals or animal feces. Contact with animal feces and fecal contaminated living environments could pose a substantial risk to human health.[48-50] For instance, children in households where domestic animals shared the same house as humans had higher odds of diarrhea and the odds of childhood diarrhea was higher in households where animal excreta was observed in child playing areas. Enteric pathogens from animal excreta could reach humans via fecal contaminated water,[30,51-53] foods,[30,54] hands,[20,30,55] and mechanical vectors.[30,56,57] In areas where open defecation is commonly practiced, animals, particularly chickens, may carry human feces and contaminate floors, food, and food utensils during scavenging, increasing the risk of disease transmission in the area. As this study depicted, children in households with no access to latrine and protected water sources had higher risk of diarrhea. Open defecation causes fecal contamination of soil and fecal contamination of soil results cross-contamination of water and foods with fecal maters, which are the main exposure pathways of diarrhea and other enteric infections.[58,59]

In the current study, we observed that domestic animals entered the human living quarter and accessed prepared and stored foods in 32% of the households and this was significantly associated with higher odds of childhood diarrhea in the study area. When domestic animals enter the human living quarters and access prepared and stored foods, they can

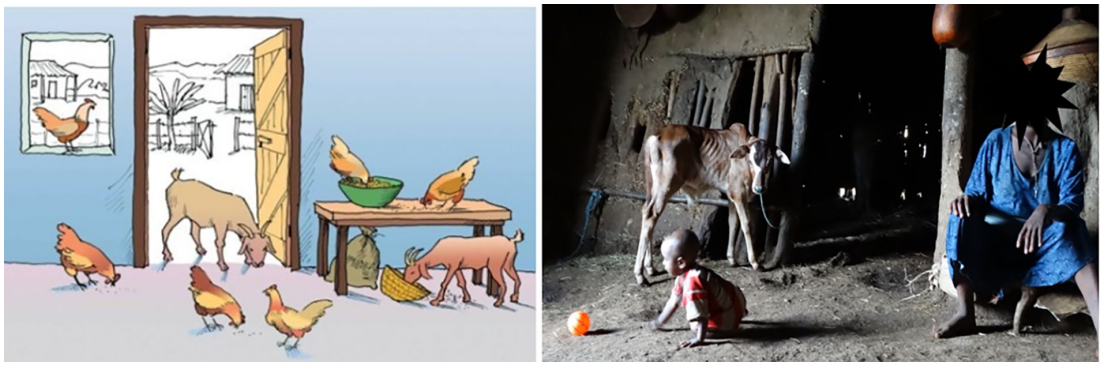

Figure 2. Pictures illustrate cross-contamination of the living environment and foods with animals in a rural setting of northwest Ethiopia.

Figure 3. Photos to show animal containment practices in a rural setting of northwest Ethiopia, May 2021.

Figure 4. Fuel disks prepared from animal dung on the wall and courtyards in a rural setting of northwest Ethiopia.

Figure 5. Cracked wall plastered with animal dungs (A) and a woman plastering floors using animal dungs with bare hands (B) in a rural setting of northwest Ethiopia.

cross-contaminate the floor and foods with fecal matter. Children might acquire diseases through mouthing of soil-contaminated materials (geophagy) and ingestion of fecal contaminated foods.[60-63]

This study revealed that all the female head of households touch animal excreta with bare hands and do not effectively wash their hands with soap in the studied region. This could be due to the rural community not perceiving that animal excreta contains pathogenic microorganisms. If a person believes that animal excreta contain infectious agents, he or she may wash hands with soap after touching it. On the other hand, a person may not effectively wash hands if he or she believes there is a low risk of infection from animals or their excreta.[37,64,65] People's beliefs and perceptions influence their behaviors as well as their ability to adapt or cope with existing health interventions.[66]

According to the findings of this study, all the households used animal dung to make fuel disks and to plaster the walls and floors of their homes with their bare hands. These practices may expose the living environment to infectious agents derived from animal waste.[12,17,67] Hands are frequently contaminated with pathogenic microorganisms when preparing fuel disks and plastering houses with bare hands.[16,68-70]

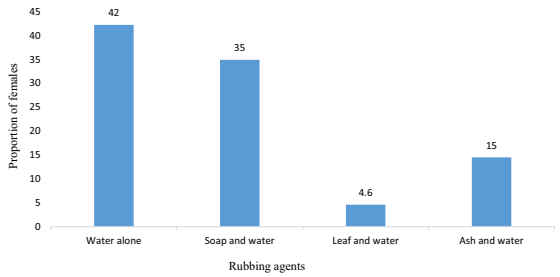

Figure 6. Rubbing agents commonly used to wash hands (n=372) after cleaning animal barns, plastered the house component, and prepared fuel disks in a rural setting of northwest Ethiopia, May 2021.

Because rural communities do not effectively and frequently wash their hands with soap, the problem of hand contamination with animal feces is recognized as a public threat.[29,71,72] We also observed dirt under the fingernails of more than two-thirds of the female head of households after they washed their hands. Dirt trapped under fingernails was significantly associated with childhood diarrhea in the study area. This association can be justified that the area beneath the fingernails that trapped dirt can harbor disease causing pathogens. These pathogens could contaminate foods during preparation or serving.[30,73,74]

In the current study, about one-third of the female head of households did not perceive that animal excreta contains infectious agents. The perception might negatively affect their attitudes or beliefs about the potential harms of animal excreta. It is widely accepted that perception is fundamental for triggering behavioral changes.[75] Those who downplay the potential harm of animal excreta or a risk event are less likely to take targeted actions to prevent the event, for instance, they may not hygienically manage animal excreta, may not contain animals, and may unnecessarily touch animal excreta with bare hands.[76] On the other hand, individuals will manage animal excreta hygienically, will contain animals or will avoid unnecessary touching of animal excreta and surfaces in close proximity to a source of contaminants, and will wash their hands frequently if they believe animal excreta contains infectious agents.[77-79]

This study provides important information on the animal handling practices of rural households that increase the risk of exposure to zoonotic agents and this information could lead to tailored public health and veterinary public health messages and interventions for the participants. However, the self-reported data may not be reliable since the study subjects may make the more socially acceptable answers rather than being truthful and they may not be able to assess themselves accurately, which might result in reporting bias.

Figure 7. Photos show hand washing facilities in rural in a rural setting of northwest Ethiopia, May 2021.

Table 4. Binary logistic regression analysis to show the association between animal handling practices and childhood diarrhea in a rural setting of northwest Ethiopia, May 2021.

VARIABLES	CHILDHOOD DIARRHEA		COR (95% CI)	AOR (95% CI)	*P*-VALUE
	YES	NO			
Domestic animals kept					
In a corral within the living space of the humans	25 (7%)	49 (13%)	1.7 (0.7, 4.1)	3.3 (1.3, 8.6)	.029
In a barn attached to the main building	55 (15%)	199 (54%)	0.9 (0.4, 2.0)	1.4 (0.6, 3.2)	.385
In a separately constructed barn	10 (3%)	34 (9%)	1.0	1.0	
Stored foods are accessible for animals					
Yes	48 (13%)	70 (19%)	3.5 (2.1, 5.7)	3.6 (2.0, 5.9)	.000
No	42 (11%)	212 (57%)	1.0	1.0	
Animal excreta in child playing areas					
Yes	75 (20%)	197 (53%)	2.2 (1.2, 4.0)	2.4 (1.2, 4.6)	.007
No	15 (4%)	85 (23%)	1.0	1.0	
Female head of households washed hands with soap after touching animal dung					
Yes	30 (8%)	100 (27%)	1.0	1.0	
No	60 (16%)	182 (49%)	1.1 (0.7, 1.8)	1.3 (0.7, 2.2)	.263
Education status of female head of households					
No formal education	95 (26%)	70 (19%)	2.2 (1.2, 4.0)	2.2 (0.5, 4.1)	.341
Attend formal education	80 (22%)	127 (34%)	1.0	1.0	
Water sources					
Unprotected	120 (32%)	76 (20%)	3.5 (2.3, 4.7)	4.2 (1.1, 15.3)	.020
Protected	55 (15%)	121 (33%)	1.0	1.0	
Defecation practice					
Open field	154 (41%)	88 (24%)	2.3 (1.8, 5.8)	3.24 (1.8, 5.9)	.000
Latrine	56 (15%)	74 (20%)	1.0	1.0	
Fingernails of female head of households had dirt					
Yes	78 (21%)	175 (47%)	4.0 (2.1, 7.6)	3.7 (1.9, 7.5)	.000
No	12 (3%)	107 (29%)	1.0	1.0	

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; COR, crude odds ratio.
1.0: Reference category of each variable, Hosmer and Lemeshow test = 0.43.

Conclusion

Domestic animals and their excreta are not properly contained in the study area. This could result in contact of rural households with animals and/or animal feces, which may pose a substantial risk to human health. Containment of animals and their excreta is needed in the area to prevent the domestic environment from fecal contamination. Because the rural communities have no alternative clean energy sources, they rely on biomass fuel energy sources, for example, fuel disks. This culturally important practice results in close contact of rural communities with animal excreta. Making animal excreta handling practices safer is very important in the area. For instance, instead of preparing fuel disks with bare hands, it is possible to use animal dung for biogas energy production. Since biogas technology is a good means of treating human and animal wastes, the local health department in collaboration with other energy sectors needs to help the community to construct a small-scale biogas plant at the household level. In addition to good animal husbandry practice (ie, containment of animals and their excreta), the hygiene behavior of female head of households such as

handwashing behaviors and food handling practices need to be improved to minimize the risk of food and hand contamination with animal excreta. Moreover, water and sanitation services should be improved in the area.

Acknowledgements
The authors are pleased to acknowledge the University of Gondar, One Health Eastern Africa Research Training (OHEART) program at the Ohio State University, Global One Health Initiative (GOHi) and National Institutes of Health (NIH) Fogarty International Center for their support.

Authors' Contributions
ZG designed the study, conducted data analysis, and produced the initial draft of the manuscript. BDB supervised data collection. AWY, JL, and MB contributed to conceptualizing the study. All authors approved the final version of the manuscript.

Availability of Data and Material
Data will be made available upon requesting the primary author.

Consent for Publication
Informed consent was obtained from female head of households to publish the information/image(s) in an online open-access publication.

Ethics Approval and Consent to Participate
Ethical clearance was obtained from the Institutional Review Board of the University of Gondar (reference number: V/P/RCS/05/1933/2020). There were no risks due to participation and the collected data were used only for this research purpose with complete confidentiality. Written informed consent was obtained from female head of households. All the methods were carried out in accordance with relevant guidelines and regulations.

ORCID iD
Zemichael Gizaw https://orcid.org/0000-0002-6713-1975

REFERENCES
1. Ellis F, Freeman HA. Rural livelihoods and poverty reduction strategies in four African countries. *J Dev Stud*. 2004;40:1-30.
2. Anderson S. Animal genetic resources and sustainable livelihoods. *Ecol Econ*. 2003;45:331-339.
3. Bonilla-Cedrez C, Steward P, Rosenstock TS, et al. Priority areas for investment in more sustainable and climate-resilient livestock systems. *Nat Sustain*. 2023;6:1279-1286.
4. Magouras I, Brookes VJ, Jori F, et al. Emerging zoonotic diseases: should we rethink the Animal-human interface? *Front Vet Sci*. 2020;7:1-6.
5. World Health Organization (WHO). Regional office for eastern the Mediterranean. Zoonotic disease: emerging public health threats in the Region. Accessed on 30 August 2022. http://www.emro.who.int/about-who/rc61/zoonotic-diseases.html.
6. World Health Organization. In Africa, 63% jump in diseases spread from animals to people seen in last decade. *WHO* 2022. Accessed on 30 August 2022. https://www.afro.who.int/news/africa-63-jump-diseases-spread-animals-people-seen-last-decade.
7. United Nations (UN). Animal-to-human diseases on the rise in Africa, warns UN health agency. Accessed on 30 August 2022. https://news.un.org/en/story/2022/07/1122522.
8. Tiwari P, Nair R, Ankinapalli P, et al. *India's Reluctant Urbanization: Thinking Beyond*. Palgrave Macmillan, 2015;153-173.
9. Byers KE, Guerrant RL, Farr BM. Fecal-oral transmission. In: Thomas JC, Webber DJ editor(s). *Epidemiologic Methods for the Study of Infectious Diseases*. Oxford: Oxford University Press, 2001:228-48.
10. Curtis V, Cairncross S, Yonli R. Domestic hygiene and diarrhoea - pinpointing the problem. *Trop Med Int Health*. 2000;5:22-32.
11. Zambrano LD, Levy K, Menezes NP, Freeman MC. Human diarrhea infections associated with domestic animal husbandry: a systematic review and meta-analysis. *Trans R Soc Trop Med Hyg*. 2014;108:313-325.
12. Delahoy MJ, Wodnik B, McAliley L, et al. Pathogens transmitted in animal feces in low- and middle-income countries. *Int J Hyg Environ Health*. 2018;221:661-676.
13. Menghistu HT, Hailu KT, Shumye NA, Redda YT. Mapping the epidemiological distribution and incidence of major zoonotic diseases in South Tigray, North Wollo and ab'ala (Afar), Ethiopia. *PLoS One*. 2018;13(12):e0209974.
14. Ministry of Agriculture and Livestock Resources and Ministry of Health. Ethiopia National One Health Strategic Plan. (2018–2022). Accessed on 07 March 2024. https://faolex.fao.org›docs›pdf›eth214405.
15. Kloos H. Health aspects of resettlement in Ethiopia. *Soc Sci Med*. 1990;30:643-656.
16. Penakalapati G, Swarthout J, Delahoy MJ, et al. Exposure to animal feces and human health: a systematic review and proposed research priorities. *Environ Sci Technol*. 2017;51:11537-11552.
17. Sobsey M, Khatib L, Hill V, Alocilja E, Pillai S. Pathogens in animal wastes and the impacts of waste management practices on their survival, transport and fate; 2006.
18. Matilla F, Velleman Y, Harrison W, Nevel M. Animal influence on water, sanitation and hygiene measures for zoonosis control at the household level: A systematic literature review. *PLoS Negl Trop Dis*. 2018;12:e0006619.
19. Alebie A, Tewachew T. Household practice related to zoonotic diseases transmission in rural community of Gondar Zuria District. *Vet Med Res Rep*. 2021;12:109-115.
20. Pickering AJ, Davis J, Walters SP, et al. Hands, water, and health: fecal contamination in Tanzanian communities with improved, non-networked water supplies. *Environ Sci Technol*. 2010;44:3267-3272.
21. Wagner EG, Lanoix JN. *Organization WH: Excreta Disposal for Rural Areas and Small Communities*. World Health Organization; 1958.
22. Barker J, Stevens D, Bloomfield SF. Spread and prevention of some common viral infections in community facilities and domestic homes. *J Appl Microbiol*. 2001;91:7-21.
23. Jumaa PA. Hand hygiene: simple and complex. *Int J Infect Dis*. 2005;9:3-14.
24. Aiello AE, Coulborn RM, Perez V, Larson EL. Effect of hand hygiene on infectious disease risk in the community setting: a meta-analysis. *Am J Public Health*. 2008;98:1372-1381.
25. Bloomfield S, Nath K. Use of ash and mud for handwashing in low income communities International Scientific Forum on Home Hygiene (IFH). In: *Somerset, England: International Scientific Forum on Home Hygiene*: 2009; 2009.
26. Ehiri J, Meremikwu M, Critchley J, Ejemot-Nwadiaro R. Hand washing for preventing diarrhoea. *Cochrane Database of Systematic Reviews* 2008, 1.
27. Freeman MC, Stocks ME, Cumming O, et al. Systematic review: hygiene and health: systematic review of handwashing practices worldwide and update of health effects. *Trop Med Int Health*. 2014;19:906-916.
28. Rabie T, Curtis V. Handwashing and risk of respiratory infections: a quantitative systematic review. *Trop Med Int Health*. 2006;11:258-267.
29. Gizaw Z, Yalew AW, Bitew BD, Lee J, Bisesi M. Effects of local handwashing agents on microbial contamination of the hands in a rural setting in northwest Ethiopia: a cluster randomised controlled trial. *BMJ Open*. 2022;12(5):e056411.
30. Gizaw Z, Yalew AW, Bitew BD, Lee J, Bisesi M. Fecal indicator bacteria along multiple environmental exposure pathways (water, food, and soil) and intestinal parasites among children in the rural northwest Ethiopia. *BMC Gastroenterol*. 2022;22:84-17.
31. East Dembiya district health department plan and monitoring office annual report 2020, by Melese Eshetie and others, Koladiba: Officer of district health department plan and monitoring office, Amhara region, Ethiopia, 2020.
32. City Population. Dembia district, Ethiopia - city Population. Accessed on 22 April 2023. https://www.citypopulation.de/en/ethiopia/admin/amhara/ET031111__dembia/.
33. Tegegne A. *Transhumance Cattle Production System in North Gondar, Amhara Region, Ethiopia: Is It Sustainable?* Vol. 14. ILRI; 2009. (aka ILCA and ILRAD).
34. Dembiya District Health Office: annual report, by Tsigereda Kefale and others, Koladiba: officer of district health office, Amhara Region, Ethiopia; 2017.
35. Deressa W, Hailemariam D, Ali A. Economic costs of epidemic malaria to households in rural Ethiopia. *Trop Med Int Health*. 2007;12:1148-1156.
36. Hasen A. Census Mapping in Ethiopia. Paper presented at: Symposium on Global Review of 2000 Round of Population and Housing Censuses: Mid-Decade Assessment and Future Prospects Statistics Division. Department of Economic and Social Affairs, United Nations Secretariat; 7-10 August, 2001; New York, NY. Accessed May 12, 2022. https://unstats.un.org/unsd/demog/docs/symposium_39.htm.
37. Lowenstein C, Roess A, Leibler JH, Graham JP, Waters WF. Animal husbandry practices and perceptions of zoonotic infectious disease risks among livestock keepers in a rural parish of Quito, Ecuador. *Am J Trop Med Hyg*. 2016;95:1450-1458.

38. Harris AR, Pickering AJ, Harris M, et al. Ruminants contribute fecal contamination to the urban household environment in Dhaka, Bangladesh. *Environ Sci Technol*. 2016;50:4642-4649.
39. Fuhrmeister ER, Ercumen A, Pickering AJ, et al. Predictors of enteric pathogens in the domestic environment from human and animal sources in rural Bangladesh. *Environ Sci Technol*. 2019;53:10023-10033.
40. Levine GA, Walson JL, Atlas HE, Lamberti LM, Pavlinac PB. Defining pediatric diarrhea in low-resource settings. *J Pediatric Infect Dis Soc*. 2017;6:289-293.
41. Overbey KN, Schwab KJ, Exum NG. Comparison of 1-week and 2-week recall periods for caregiver-reported diarrhoeal illness in children, using nationally representative household surveys. *Int J Epidemiol*. 2019;48:1228-1239.
42. Gizaw Z, Biks GA, Yitayal M, et al. Sanitation predictors of childhood morbidities in Ethiopia: evidence from Dabat Health and Demographic Surveillance System. *Environ Health Prev Med*. 2019;24:43-48.
43. Kayser GL, Moriarty P, Fonseca C, Bartram J. Domestic water service delivery indicators and frameworks for monitoring, evaluation, policy and planning: a review. *Int J Environ Res Public Health*. 2013;10:4812-4835.
44. United Nations Educational, Scientific and Cultural Organization (UNCEF). Monitoring progress in the water sector: A selected set of indicators. UN-Water Task Force on Indicators, Monitoring and Reporting. Accessed on 25 February 2024. https://www.unwater.org/sites/default/files/app/uploads/2017/05/TFIMR_Annex_FinalReport.pdf.
45. StataCorp. *Stata Statistical Software: Release 14*. StataCorp LLC; 2015.
46. Sun G-W, Shook TL, Kay GL. Inappropriate use of bivariable analysis to screen risk factors for use in multivariable analysis. *J Clin Epidemiol*. 1996; 49:907-916.
47. Wallisch C, Bach P, Hafermann L, et al. Review of guidance papers on regression modeling in statistical series of medical journals. *PLoS One*. 2022;17(1): e0262918.
48. Lowenstein C, Vasco K, Sarzosa S, et al. Determinants of childhood zoonotic enteric infections in a semirural community of Quito, Ecuador. *Am J Trop Med Hyg*. 2020;102:1269-1278.
49. Barnes AN, Davaasuren A, Baasandavga U, et al. Zoonotic enteric parasites in Mongolian people, animals, and the environment: Using One Health to address shared pathogens. *PLoS Negl Trop Dis*. 2021;15(1):e0009543.
50. Angulo FJ, Steinmuller N, Demma L, et al. Outbreaks of enteric disease associated with animal contact: not just a foodborne problem anymore. *Clin Infect Dis*. 2006;43:1596-1602.
51. Dufour A, Bartram J. *Animal Waste, Water Quality and Human Health*. IWA publishing; 2012.
52. Schriewer A, Odagiri M, Wuertz S, et al. Human and animal fecal contamination of community water sources, stored drinking water and hands in rural India measured with validated microbial source tracking assays. *Am J Trop Med Hyg*. 2015;93:509-516.
53. Pandey PK, Kass PH, Soupir ML, Biswas S, Singh VP. Contamination of water resources by pathogenic bacteria. *AMB Express*. 2014;4:51-16.
54. Gerba CP. Environmentally transmitted pathogens. In: Raina MM, Ian LP editor(s). *Environmental Microbiology*. Elsevier; 2009:445-484.
55. Bloomfield SF, Aiello AE, Cookson B, O'Boyle C, Larson EL. The effectiveness of hand hygiene procedures in reducing the risks of infections in home and community settings including handwashing and alcohol-based hand sanitizers. *Am J Infect Control*. 2007;35:S27-S64.
56. Cocciolo G, Circella E, Pugliese N, et al. Evidence of vector borne transmission of Salmonella enterica enterica serovar gallinarum and fowl typhoid disease mediated by the poultry red mite, Dermanyssus gallinae (De Geer, 1778). *Parasit Vectors*. 2020;13:1-10.
57. Graczyk Z, Graczyk T, Naprawska A. A role of some food arthropods as vectors of human enteric infections. *Open Life Sci*. 2011;6:145-149.
58. Sclar GD, Penakalapati G, Amato HK, et al. Assessing the impact of sanitation on indicators of fecal exposure along principal transmission pathways: a systematic review. *Int J Hyg Environ Health*. 2016;219:709-723.
59. Goddard FGB, Pickering AJ, Ercumen A, et al. Faecal contamination of the environment and child health: a systematic review and individual participant data meta-analysis. *Lancet Planet Heal*. 2020;4:e405-e415.
60. Medgyesi D, Brogan J, Sewell D, et al. Where children play: Young child exposure to environmental hazards during play in public areas in a transitioning internally displaced persons community in Haiti. *Int J Environ Res Public Health*. 2018;15:1646.
61. George CM, Oldja L, Biswas S, et al. Geophagy is associated with environmental enteropathy and stunting in children in rural Bangladesh. *Am J Trop Med Hyg*. 2015;92:1117-1124.
62. Nicole Coglianese M, Elizabeth Thomas M, Sarah Bauler M, et al. Child Mouthing of Feces and Fomites and Animal Contact are Associated with Diarrhea and Impaired Growth Among Young Children in the Democratic Republic of the Congo: A Prospective Cohort Study.
63. Kwong LH, Ercumen A, Pickering AJ, et al. Ingestion of fecal bacteria along multiple pathways by young children in rural Bangladesh participating in a cluster-randomized trial of water, sanitation, and hygiene interventions (WASH benefits). *Environ Sci Technol*. 2020;54:13828-13838.
64. Osbjer K, Boqvist S, Sokerya S, et al. Household practices related to disease transmission between animals and humans in rural Cambodia. *BMC Public Health*. 2015;15:476-510.
65. Alarcon P, Wieland B, Mateus A, Dewberry C. Farmers' perceptions, attitudes, influences and management of information in the decision-making process for disease control. *Society for Veterinary Epidemiology and Preventive Medicine Proceedings of a meeting held in Madrid, Spain, 20-22 March 2013: 2013*: Society for Veterinary Epidemiology and Preventive Medicine; 2013: 211-225.
66. Mubyazi G, Barongo V, Kamugisha M, Njunwa K. Public knowledge, perceptions and practices in relation to infectious and other communicable diseases in Tanzania: Lessons learnt from Babati district. *Rwanda J Health Sci*. 2013;2:1-12.
67. Cox P, Griffith M, Angles M, Deere D, Ferguson C. Concentrations of pathogens and indicators in animal feces in the Sydney watershed. *Appl Environ Microbiol*. 2005;71:5929-5934.
68. Nyariki DM, W. Mwang'ombe A, Thompson DM, D, Land-use change and livestock production challenges in an integrated system: the Masai-Mara ecosystem, Kenya. *J Hum Ecol*. 2009;26:163-173.
69. Sprenger LK, Green KT, Molento MB. Geohelminth contamination of public areas and epidemiological risk factors in Curitiba, Brazil. *Revista Brasileira de Parasitologia Veterinária*. 2014;23:69-73.
70. Anuar TS, Al-Mekhlafi HMS, Ghani MKA, Moktar N. Prevalence and risk factors associated with Entamoeba histolytica/Entamoeba dispar/Entamoeba moshkovskii complex infection among different tribes of malaysian aborigines. *Int J Infect Dis*. 2012;16:e175-e176.
71. Kashiwase H. Many homes in low- and lower middle-income countries lack basic handwashing facilities. Accessed on 29 August 2022. https://www.ndtv.com/world-news/most-homes-in-low-income-countries-dont-have-access-to-soap-1717147.
72. NDTV. 'Most Homes In Low-Income Countries Don't Have Access To Soap'. Accessed on 29 August 2022. https://www.ndtv.com/world-news/most-homes-in-low-income-countries-dont-have-access-to-soap-1717147.
73. Bajirova M. Hygiene and health in Quran and Science. *EC Gynaecology*. 2017;1:44-55.
74. Tambekar S, Tiwari R. Microbiological analysis of Female fingernails collected from Gondia district of Maharashtra; 2018.
75. Kim C, Song H. Structural relationships among public's risk characteristics, trust, risk perception and preventive behavioral intention: the case of MERS in Korea. *Crisisnomy*. 2017;13:85-95.
76. Slovic P. Perception of bisk. *Science*. 1987;236:280-285.
77. Anthonj C, Setty KE, Ferrero G, et al. Do health risk perceptions motivate water - and health-related behaviour? A systematic literature review. *Sci Total Environ*. 2022;819:1-25.
78. Novotný J, Kolomazníková J, Humňalová H. The role of perceived social norms in rural sanitation: an explorative study from infrastructure-restricted settings of South Ethiopia. *Int J Environ Res Public Health*. 2017;14:794.
79. Novotný J, Ficek F, Hill JKW, Kumar A. Social determinants of environmental health: A case of sanitation in rural Jharkhand. *Sci Total Environ*. 2018; 643:762-774.