



# A Systematic Review of Water and Gender Interlinkages: Assessing the Intersection With Health

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**Background:** Significant developmental challenges in low-resource settings limit access to sustainable water, sanitation, and hygiene (WASH). However, in addition to reducing human agency and dignity, gendered WASH inequities can also increase disease burden among women and girls. In this systematic review, a range of challenges experienced by women relating to inadequate WASH resources are described and their intersection with health are explored. We further assess the effectiveness of interventions in alleviating inequalities related to the Sustainable Development Goals (SDGs) three (health), five (gender), and six (water).

**Methods:** We searched the MEDLINE database to identify research articles related to water (i.e., WASH), gender, and sustainability. An analysis of both observational and interventional studies was undertaken. For each study, content analysis was performed to identify the relevant WASH, gender, and health related outcomes, and the main conclusions of the study.

**Results:** Key themes from our search included that women and girls face barriers toward accessing basic sanitation and hygiene resources, including a lack of secure and private sanitation and of Menstrual Hygiene Management (MHM) resources. In total, 71% of identified studies reported a health outcome, suggesting an intersection of water and gender with health. Half of the research studies that included a health component reflected on the relationship between WASH, gender, and infantile diseases, including under-5 mortality, waterborne parasites, and stunting. In addition, we found that women and girls, as a result of their role as water purveyors, were at risk of exposure to contaminated water and of sustaining musculoskeletal trauma. A limited number of studies directly compared gender differences in accessing WASH resources, and an even smaller fraction ( $N = 5$ , 8.5%) reported sex-disaggregated outcomes. Educational, infrastructural, and programmatic interventions showed promise in reducing WASH and health outcomes. Indeed, infrastructural WASH interventions can be successful if long-term maintenance is ensured.

**Conclusions:** Significant WASH inequities in women and girls further manifest as health burdens, providing strong evidence that the water-gender-nexus intersects with health.

Thus, addressing gender and water inequities holds the potential to alleviate disease burden and have a significant impact on achieving the SDGs, including SDG three, five, and six.

**Keywords:** water, gender, health, sustainable development goals, WASH, hygiene

## INTRODUCTION

### Rationale

Water is necessary for life, and for numerous derived essential applications ranging from industry, agriculture, drinking, sanitation, and hygiene. The Joint Monitoring Program (JMP) describes how among the least developed countries, 35% lacked access to basic water needs (i.e., water from an improved water source which can be retrieved within a 15 min round trip), 65% lacked access to basic sanitation (i.e., a toilet or latrine which protects against soil leaching by contaminants), and 73% lacked access to basic hygiene (i.e., a handwashing facility with soap and water) (WHO and UNICEF, 2019). These staggering statistics point to a lack of critical human development, especially for the vulnerable and marginalized populations. Recognizing the importance of accessing water, the Sustainable Development Goals (SDGs), as demonstrated by SDG 6 which emphasizes “*clean water and sanitation*” (targets 6.1 and 6.2), outline indicators for ensuring sustainable and equitable access to water for all. Broadly, these SDG targets focus on providing ubiquitous access to sustainable water, basic sanitation and hygiene (WASH) to redress deficiencies prevalent among low- and middle- income countries (LMICs) and populations living in vulnerable situations (Nagabhatla et al., 2019).

It is paramount to recognize that inequities in accessing WASH resources are further exacerbated among specific populations. For example, rural populations and women represent marginalized groups who are unduly encumbered by poor WASH practices or face additional challenges in accessing WASH resources (WHO and UNICEF, 2019). Women and girls disproportionately serve as water purveyors, collecting water in eight of 10 households, and as such, often face the burdens of needing to transit long distances to retrieve water (WHO and UNICEF, 2017). Moreover, women and girls require additional resources to address their menstrual hygiene management (MHM) needs. According to the 2017 JMP report (WHO and UNICEF, 2017), MHM is stated as, “...using a clean menstrual management material to absorb or collect menstrual blood, that can be changed in privacy as often as necessary for the duration of a menstrual period, using soap and water for washing the body as required, and having access to safe and convenient facilities to dispose of used menstrual management materials.” MHM is instrumental in progressing women’s and girls’ ability to manage their menstrual periods safely and with dignity; thereby, allowing them to participate in school, work, and other activities (Sommer et al., 2016). In general, WASH-related challenges among women are often exacerbated by women’s general reduced agency in low-resource settings and need to be appropriately addressed to ensure gender equity objectives.

Despite these gender-related deficiencies, research assessing the intersection between gender and water is severely lacking

and remediating gender-water inequities will require targeted resources to fill in the gaps. For example, the 2014 JMP report did not collect sex-disaggregated data, and in 2015, it reported obstacles in collecting sex-disaggregated data (Fletcher and Schonewille, 2015). The 2014 UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water survey also entirely excluded sex-disaggregated data reporting (Fletcher and Schonewille, 2015). In 2019, the World Water Development Report likewise highlights this gap, more specifically related to WASH and MHM related challenges for populations living in vulnerable situations (Nagabhatla et al., 2019).

There are further interlinkages existing between water, gender, and health- worsening WASH-inequities among women cause associated health burdens. Among other burdens, poor WASH practices elevate the risk for waterborne diseases, including for example cholera, a bacterial infection and transmitted by contaminated water and poor sanitation and hygiene practices (Mahamud et al., 2011; Fletcher and Schonewille, 2015). Given the role of women in water provisioning for households, they are at an increased risk of exposure to transmission and contraction of disease (World Health Organization, 2011). Likewise, urinary tract infections (UTIs) as a result of poor MHM practices, can result in school absences and an overall reduced education (Sommer et al., 2016).

In this way, the SDGs are uniquely interconnected, particularly with respect to accessing water, as the SDG 6 Synthesis Report (2018) reflects—“*Water resources are embedded in all forms of development (e.g., food security, health promotion, and poverty reduction), in sustaining economic growth in agriculture, industry and energy generation, and in maintaining healthy ecosystems*” (United Nations, 2018). Despite this, a detailed understanding of the interlinkages between water and gender is lacking. Moreover, given that the health burdens associated with poor WASH can disproportionately entangle women, the water-gender interlinkages with health need to be carefully examined and, subsequently, integrated into policies.

One step toward helping fill this gap has been the work completed by United Nations Educational, Scientific and Cultural Organization (UNESCO) in developing the Water and Gender toolkit for collecting sex-disaggregated data in the water sector [World Water Assessment Programme (UNESCO WWAP), 2019]. The updated toolkit introduces a set of new indicators to better elucidate how women and girls experience inequities related to accessing or making decisions regarding water and water-related tasks [World Water Assessment Programme (UNESCO WWAP), 2019]. However, more work is needed to understand the landscape of the water-gender nexus as it has currently been described in the literature, and to interrogate its intersection with health.

## Objectives

To survey observational and interventional studies of adults and children conducted globally to identify the range of WASH challenges experienced by women; identify major health burdens associated with lacking WASH provisions, and specifically within women; identify key themes of WASH interventions for addressing burdens associated with the water, gender, and health interlinkages.

## Research Question

This research aimed to interrogate the question, do WASH based deficiencies disproportionately burden women? If so, do these deficiencies manifest through augmenting health burdens among women and girls?

## METHODS

### Study Design

We conducted a systematic review using a broad-based content analysis through the PRISMA guidelines. This approach was adopted for an investigation that aimed to include key highlights identified by each study with respect to the water-gender interlinkages and its intersection with health.

### Participants

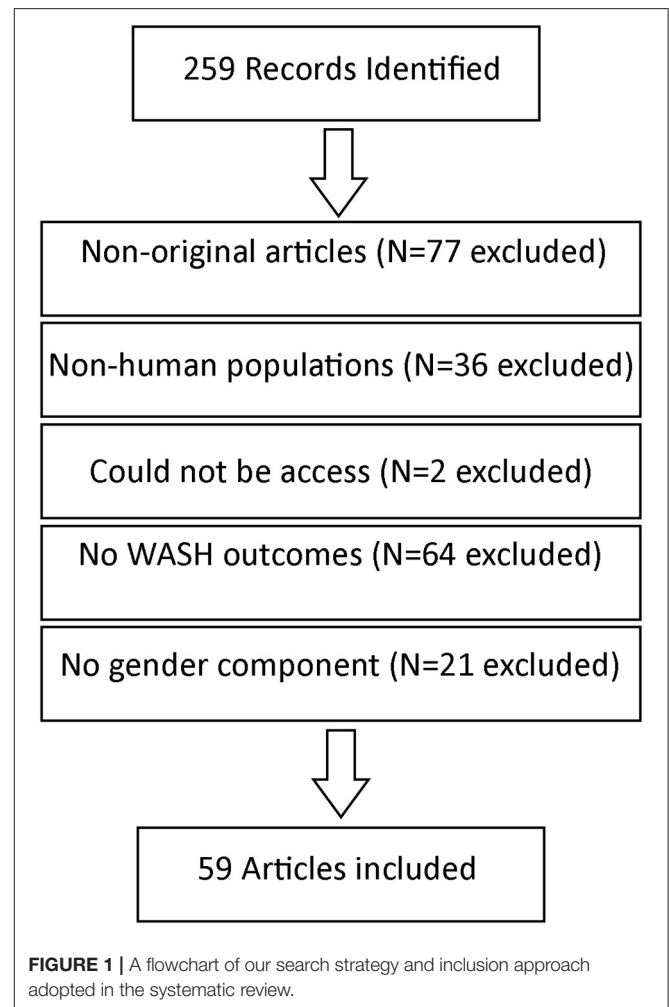
For each paper, the population of women was considered and was subdivided into three categories: (1) girl/adolescent, (2) pregnant/maternal women, (3) household/adult women. WASH was categorized with respect to whether it addresses (1) water, (2) sanitation, (3) hygiene, or (4) MHM. Health outcomes were categorized based on the disease or the burden described. For each WASH and health outcome, relevant outcomes relating to poor WASH accessibility, or health were described. Where available, an assessment of whether the study directly compares gender, and whether poor WASH or health outcomes were gender specific was considered. In studies that focused solely on women, whether specific gender-based challenges are identified and documented was also noted.

### Search Strategy

A two-phase strategy was adopted to search the literature for documents/papers mining. A comprehensive keyword search of the primary literature was conducted using the MEDLINE database. After excluding irrelevant papers, in phase 2, a broad content analysis was adopted to identify relevant, and broad-reaching WASH and health data information. A single search approach was used to first comprehensively identify articles related to the water-gender nexus. Subsequently, these articles were analyzed to determine whether a health component was present. In short, a selection criterion was outlined and adopted to shortlist the papers.

### Phase 1: Search Strategy and Aggregation of Data and Information

A systematic review of MEDLINE publications via PubMed was used. Search terms surrounding three categories [gender, water, and sustainability], were incorporated in the search query.



For each category, terms spanning multiple dimensions of that theme and derived words were searched. For instance, the search terms for gender included: woman, women, female, sex, gender, girls, girl, gender equality, gender gap, women's empowerment, and women empowerment. In addition, for water: WASH, water sanitation and hygiene, sanitation, clean water, safe water, hygiene, water access, water security, water availability, water collection, water management, fetching water, water fetching, drinking water, water sources, and water source. The search terms for sustainability included: sustainable development goal, sustainable development goals, sustainable development, SDG, SDGs, sustainability, and sustainable.

Our inclusion criteria included observational studies and clinical trials that utilized a quantitative, qualitative, or mixed-methods design; was available in English; contained a WASH outcome; and explicitly considered a gendered outcome (i.e., in women or girls, or gender/sex differences). Exclusion criteria included studies not focused on humans, that did not provide primary data or analysis (i.e., commentaries, systematic reviews, literature reports) and did not consider a population (i.e., case reports). **Figure 1** provides a flowchart of the methodological approach.

## Phase 2: Criteria Based Analysis

For each of the selected research papers, data were collected describing the study design, location, population, WASH outcomes, health outcomes, whether the study was sex-disaggregated, and the key highlights. For interventional studies, information describing the intervention were examined. Sex-disaggregated data was defined as data whereby indicators for men and women are separately provided.

## Assessing Risk of Bias

We assessed the risk for bias in individual studies using a previously validated adaptation of the Cochrane risk of bias instrument (Akl et al., 2012). Bias is assessed based on the response options “definitely yes or no” or “probably yes or no” to criteria highlighted separately for cross-sectional, cohort, and randomized control trials (Supplemental Tables 1–3). Questions include for example, “Is the source population representative of the population of interest?” where affirmative answers indicate less bias, and negative responses indicating greater bias. Information regarding the risk of bias tools used can be found at <https://www.evidencepartners.com/resources/methodological-resources>.

In brief, cross-sectional studies with low bias are characterized by the demonstrated use of a valid sampling strategy (e.g., simple sampling, cluster sampling, etc.); an adequate participant response/inclusion rate; little reported missing data; the inclusion of relevant outcome measures; and validation of the data collection method (e.g., pilot testing, previously validated approach).

Cohort studies with low bias are characterized by evidence that individual cohorts are drawn from a common underlying population (i.e., similar communities which deviate mainly due to exposure to the factor of interest); use satisfactory data collection modalities for relevant factors, outcomes, and confounds; ensure that baseline levels of the outcome of interest are absent or equally low; ensure minimal differences in other confounding variables, or, use appropriate statistical methods to account for confounds (e.g., matching, or regression); use an appropriate follow-up strategy with a high degree of participant retention; are not impacted by the differential exposure to other interventions/ameliorating strategies (e.g., free education is present in only one community).

Randomized control trials with low bias ensure the random allocation of patients to the respective treatment groups (e.g., simple random stratification, matched stratification); that the randomization procedure is concealed; adequate blinding of participants, healthcare providers, data collectors, outcome assessors, and data analysts; a low loss to follow-up; report all pre-determined outcome measures (e.g., do not selectively withhold results, or statistical analyses); and was generally conducted in a statistically sound, valid, and reliable manner (e.g., use appropriate data collection instruments, have appropriate controls).

## RESULTS

### Study Selection and Characteristics

This analysis identified 59 research articles from 30 countries published between 1993 and 2019. Close to half of the publications conducted analyses in Sub-Saharan Africa with Kenya ( $N = 7$ ) and Nigeria ( $N = 5$ ) representing the most frequently studied countries. **Table 1** describes 46 identified observational studies included in the analysis, while **Table 2** describes 13 identified interventional studies. Primarily, WASH studies focused on measuring access to water (74%), followed by access to sanitation (54%), hygiene (10%), and MHM (7%). As well, close to half of studies (46%) focused exclusively on the experience of women and girls and did not consider impacts on men. Only five publications (8.5%) reported some sex-disaggregated outcomes.

### Synthesized Findings

#### Women Are the Primary Water Purveyors, Particularly in the Developing Regions of the World

Largely, the identified observational studies (**Table 1**) emphasized issues in accessing clean water among women and girls, and described that a lack of clean water and water resources negatively contributed to women and girl's health and quality of life (Doherty et al., 2007; Bornman et al., 2012; Sato et al., 2016; Gaspar et al., 2017; Vos et al., 2017; Angoua et al., 2018; Prado et al., 2019). Studies which considered gender likewise revealed a lack of access to improved water for both men and women alike (Ugbomoiko et al., 2009; Al-Delaimy et al., 2014; Atalabi et al., 2016; Holvoet et al., 2016; Akombi et al., 2017; Baker et al., 2018). Few studies directly compared whether access to water differed as a result of a gender. However, Bisung and Elliott (2018) showed that female-headed households had reduced access to water security (Bisung and Elliott, 2018). Moreover, within a household, there was substantial evidence that women as the primary carriers of water with prevalence estimates ranging from 61 to 79% (Hunter, 2006; Bornman et al., 2012; Holvoet et al., 2016; Geere et al., 2018). Indeed, the presence of a wife in the household significantly increased the likelihood of having access to clear water (Angoua et al., 2018). Mean travel times for fetching water were as high as 54 min (Holvoet et al., 2016). Consequently, poor access to water at a household level disproportionately impacts women and girls who are commonly responsible for securing water.

#### Women Face Unique WASH and MHM Challenges

A multitude of studies focused on women and girls and demonstrated that women practiced poor sanitation, hygiene, and MHM practices, largely due to lacking resources. Sanitation facilities were commonly cited to not be safe, clean, and accessible (Kwiringira et al., 2014; Sato et al., 2016; Khan et al., 2017; Aluko et al., 2018; Angoua et al., 2018; Dendup et al., 2018; Desalegn et al., 2018; Njuguna, 2019; Winter et al., 2019). Basic needs, such as soap and washing facilities, and hygienic products, such as toothpaste were documented as hygiene barriers (Budhathoki et al., 2018; Lubon et al., 2018). Moreover, women and girls often cited that critical challenges

**TABLE 1** | Observational studies from the systematic review to assess the water-gender nexus (focused on WASH) with the inclusion of health outcomes.

References	Country	Study design	Sample size	Health component	WASH outcome	Gender outcome	Sex disaggregated	Conclusion
Acheampong et al. (2017)	High, low and middle-income countries	Modeling	109 countries	Under-five mortality	Access to an improved water source, improved sanitation	Considered the impact of female employment and female literacy rates.	No	Improved access to drinking water and sanitation correlated with a reduced under-5 mortality rate; female metrics had no effect.
Acheampong et al. (2018)	Africa	Cross-sectional	43 countries	Under-five mortality	Access to an improved water source, improved sanitation	Considered female employment and literacy rates.	No	Access to improved water and sanitation reduced under-five mortality, and engendered variables had no effect.
Ahmed et al. (2016)	Global	Mixed methods	10 countries	Under-five mortality	Access to an improved water source, and sanitation.	Levels of female education and employment.	No	Among others, policies which increased investment in girl's education and improved access to water, sanitation, and hygiene were implemented in countries successful in reducing the under-5 mortality and thus, was attributed to their success.
Aiemjoy et al. (2017)	Ethiopia	Cross-sectional	278 households, 15 focus group discussions	N/A	Access to a household latrine	Assessed differences between male and female headed households.	No	Male-headed households were 3.5-fold more likely to use latrines than households with female heads. Women preferred not to use latrines and considered them scary. Having children in school improved the odds of having a latrine by 2-fold. Economic indicators did not serve as a barrier.
Akachi et al. (2018)	Sub-Saharan Africa	Longitudinal	562, 896 children	Under-five mortality	Access to an improved water source, and in-house sanitation facilities; handwashing frequency	Considered maternal factors.	No	After confound adjustment, high-quality water and sanitation had no effect on under-5 mortality. Female education reduced under-5 mortality.
Akombi et al. (2017)	Nigeria	Cross-sectional	24,529 children aged 0–59 months old.	Child stunting	Access to an improved water source	Compared gender differences.	No	Four in 10 used water from an unimproved source. Male children were more likely to be stunted in comparison to females for both 0–23 months and 0–59 months old. Access to an improved drinking water decreased the odds of stunting by ~30% in children aged 0–59 months old.

*(Continued)*

TABLE 1 | Continued

References	Country	Study design	Sample size	Health component	WASH outcome	Gender outcome	Sex disaggregated	Conclusion
Al-Delaimy et al. (2014)	Malaysia	Cross-sectional	498 school children aged 6–12 years old	Intestinal parasitic infections	Access to piped water, handwashing, and sanitation.	Considered the effect of sex.	No	48.8% of children had access to piped water, 46.4% possessed an in-house toilet. Unsafe water and the absence of a toilet increased the risk of infection by 2-fold. Not washing hands before eating, not cutting nails, and not wearing shoes increased the risk of infection by 1.5-fold, while not washing fruits and vegetables increased the risk of infection by 2.5-fold. Sex had no effect.
Alemu et al. (2017)	Ethiopia	Cross-sectional	3,108 children, aged 6–59 months old.	Child stunting	Household level of water treatment; latrine usage	Considered the effect of gender	No	Household level of water treatment improved child height ( $p < 0.05$ ). 23% of households used latrines which reduced stunting (OR: 0.39). Stunting prevalence differed between boys (41.7%) and girls (37%), and being female improved the child's height.
Aluko et al. (2018)	Nigeria		312 individuals	N/A	Knowledge of hygiene and sanitation practices	Assessed gender differences.	No	Reported knowledge on shared household sanitation practices were good (66.3% correct answers); however, 60.3% of shared sanitation facilities were dirty. 62.8% of respondents had access to a toilet.
Angoua et al. (2018)	Côte d'Ivoire	Cross-sectional	556 households	No	Access to clean water, and improved sanitation	The presence of women in the household was a considered factor.	No	Nearly 1 in 4 households lacked access to clean water, 57% lacked improved sanitation. Having the head of the household's wife in the home improved access to clean water by 3-fold.
Atalabi et al. (2016)	Nigeria	Cross-sectional	718 students	Prevalence of genito-urinary schistosomiasis	Access to an improved water source	Considered gender differences and maternal factors.	No	22.7% of students possessed genito-urinal schistosomiasis. Boys were 7-fold more likely to be infected with schistosomiasis. Unclean water was associated with increased infections, as were mothers who were employed as "brown collared workers" or were homemakers.

(Continued)

TABLE 1 | Continued

References	Country	Study design	Sample size	Health component	WASH outcome	Gender outcome	Sex disaggregated	Conclusion
Baker et al. (2018)	Togo	Cross-sectional	16,473 children in 2009, 16,890 in 2016	Prevalence of hookworm infection	Access to an improved water source, improved sanitation, and handwashing stations.	Compared gender differences.	No	1 in 2 children had access to improved water, 3 in 10 had access to a latrine. Prevalence of hookworm decreased from 32.4% in 2009 to 11.1% in 2015 across all schools. Unimproved drinking water sources increased the odds of hookworm infection by 1.4-fold. Access to an improved drinking water off school grounds, and handwashing stations further reduced hookworm eggs in stool by 20% each. Boys had nearly twice as many hookworm eggs in their stool than girls in both 2009 and 2015.
Bisung and Elliott (2018)	Kenya	Cross-sectional	557 households	N/A	Access to an improved water source	Assessed differences between male and female headed households.	No	72% accessed piped water outside their household premises. Round trips for collecting water took, on average, 7 min. Female headed households experienced less water security than male headed households.
Bornman et al. (2012)	South Africa	Cross-sectional	156 female caregivers	Concern of malaria	Access to clean water	Focused on women.	No	Women were the primary collectors of water. Between 8 and 23% of women cited a lack of clean water as a daily concern. Between 86 and 93% of women attributed malaria to mosquitos, and the remainder of women associated malaria with dirty, stagnant water.
Braxton and Larson (2019)	Guatemala	Cross-sectional	10 Mayan caregivers	Conception of health	Access to clean water	Mostly women were interviewed.	No	Access to clean drinking water was universally linked to the concept of good health
Budhathoki et al. (2018)	Nepal	Cross-sectional	117 women and adolescent girls	N/a	Access to MHM and hygiene resources; private safe locations	Focused on women's needs following an earthquake.	No	Half of women and girls received soap. 1 in 5 women listed MHM as a need. No women received any menstrual hygiene adsorbents in the distributed relief materials within the 1st month following the disaster. Three-quarters of respondents used reusable cloths for managing menstrual bleeding. Less than half reported the availability of private, safe locations for attending to MHM needs.

(Continued)

TABLE 1 | Continued

References	Country	Study design	Sample size	Health component	WASH outcome	Gender outcome	Sex disaggregated	Conclusion
Davis et al. (2018)	Indonesia	Cross-sectional	1,159 adolescent girls	No	Access to MHM and hygiene resources	Focused on adolescent school girls.	No	<10% of girls used reusable cloths and over half changed cloths at least every 4–8 days. 95% washed their genitals daily. In total, over 60% of girls reported poor MHM practices.
Dendup et al. (2018)	Bhutan	Cross-sectional	39,789 individuals from 13,256 households	Under-five mortality	Access to a safe drinking water source water, sanitation facilities	Considered maternal and gender indicators.	No	A lack of safe sanitation facilities increased the odds of under-five mortality by 1.5-fold, and access to safe water had no effect. Among gender-related factors, mothers who were older than 25 reduced the risk of under-five mortality by 2–5-fold. Other gender related factors had no effect.
Desalegn et al. (2018)	Ethiopia	Cross-sectional	572 lactating mothers fasting during lent, 522 non-fasting lactating mothers	Frequency of underweight mothers	Access to an improved water source, and a household toilet.	Focused on lactating mothers.	No	Fasting mothers without a non-improved water source, or a toilet were 1.6-fold, and 1.5-fold, respectively more likely to be underweight.
Doherty et al. (2007)	South Africa	Prospective cohort	635 mothers	HIV-free status of infants	Access to piped water	Focused on maternal factors.	No	Piped water was one of three criteria necessary for appropriate formula use. Women who used formula without the appropriate conditions, or who breast-fed their children had a 3-fold increased risk of infant HIV transmission.
Donohue et al. (2017)	Kenya	Cross-sectional	1,704 school children	Prevalence of schistosomiasis	Access to clean water, sanitation; exposure to open-water sources	Compared gender differences.	No	A lack of latrines and safe drinking water increased self-reported schistosomiasis by 2.5 and 3-fold, respectively. Frequent visits to the river (>1+ per day) reduced risk. Boys were 2.5-fold more likely to self-report schistosomiasis.
Fuge et al. (2015)	Ethiopia	Cross-sectional	398 Pregnant women/ mothers	Malaria transmission and infection	knowledge of sanitation and hygiene practices	Pregnant women were the focused population.	No	261 women (66%) responded that malaria was transmitted due to poor personal hygiene and environmental sanitation.
Gaspar et al. (2017)	South Africa	Cross-sectional	751 mothers	Serum concentration of the anti-malaria chemicals dichlorodiphenylchloroethane (DDT) and dichlorodiphenyldichloroethylene (DDE)	Access to an improved water source; frequency of washing the household	Focused on pregnant women.	No	Living further from an open body of water, having in-house piped water, and mopping the house 7-times weekly decreased DDT exposure.

(Continued)



TABLE 1 | Continued

References	Country	Study design	Sample size	Health component	WASH outcome	Gender outcome	Sex disaggregated	Conclusion
Geere et al. (2018)	South Africa, Ghana and Vietnam	Cross-sectional	3, 365 adults and children	Self-reported pain	Method and frequency of carrying water	Focused on outcomes in women and girls.	No	Carrying water increased pain in the upper back by 2-fold and in the hands by 3-fold compared to those who never carried water.
Guy et al. (2018)	Benin	Cross-sectional	65 women	Presence of heavy metals in the plasma of pregnant and birthing women.	Type of primary water source	Focused on pregnant women.	No	Compared with running water, women who received water from a drill-pump possessed higher levels of lead in their blood during the first trimester.
Hall and Le (2018)	Vietnam	Cross-sectional	600 small scale farms	Implementation of waterborne disease mitigation strategies	Type of primary water source	Assessed gender differences in decision-making.	No	Rain water or a drilled well as the primary water source increased the odds of engaging in mitigation by 1.5 and 2-fold, respectively. Female healthcare decision makers increased the odds of mitigation by 1.5-fold.
Hasan and Richardson (2017)	Bangladesh, Nepal, and Pakistan	Cross-sectional	23, 940 children	Diarrhea and acute respiratory infections in children	Access to improved water and sanitation	Considered maternal factors.	No	In adjusted analyses, across Nepal, Pakistan, and Bangladesh, a mother's incomplete secondary or primary education increased the odds of contracting diarrhea by 1.2–1.7-fold. The water source or level of sanitation had little impact on the incidence of morbidity in children.
Holvoet et al. (2016)	Uganda	Cross-sectional	126 adults >25 years old	N/A	Access to clean water; Time spent seeking water	Assessed gender differences in how water-related information was shared in the community	No	42% of adults reported a lack of water sources, and 79% reported water was too far away. Households possessed a lack of clean water nearly half of the time. The average time to retrieve water was 54 min. Participants of the same sex were 2.2 times more likely to share information on water access.
Hunter (2006)	Ghana	Cross-sectional	700 households, 1,624 individuals	Considered the relative importance of accessing health services.	Frequency and length water fetching trips; attitudes on importance of water access.	Assessed gender differences.	Yes	Female heads/partners (~40%) and daughters (~20%) were the primary water carriers. Regardless of the time it took for water fetching, improving water access was prioritized more than improving employment opportunities. Male headed households, and sons traveling > 15 min to fetch water were > 10-fold more likely to state water access as a more important priority than health services. Girls who traveled < 15 min were 8.5-fold more likely to declare employment as an important priority than water access.

(Continued)

TABLE 1 | Continued

References	Country	Study design	Sample size	Health component	WASH outcome	Gender outcome	Sex disaggregated	Conclusion
Inobaya et al. (2018)	The Philippines	Cross-sectional	2,189 adults, > 18 years old	Compliance to drug regimen	Knowledge of water and sanitation practices	Assessed gender differences	No	Those who believed that open defecation and poor sanitation were mechanisms of infection and those who believed that avoiding dirty drinking water could prevent schistosomiasis were 1.4-fold and 2.1-fold more likely to not comply with schistosomiasis chemotherapy. However, those who believed schistosomiasis could be transmitted by dirty water, and were over 30 years old, were 3–5-fold more likely to be compliant. Women were 1.7-fold more likely to not comply with treatment.
Kapito-Tembo et al. (2009)	Malawi	Cross-sectional	1,150 students	Prevalence of schistosomiasis	Proximity to open water	Assessed gender differences.	No	Schistosomiasis eggs were detected in 10% of students. Male students were at a 1.8-fold increased risk of schistosomiasis eggs. Knowledge of an open water source and having an open-water source within 1 km of the school increased the risk of infection by 1.9-fold and 5.4-fold, respectively.
Khan et al. (2017)	Belize	Cross-sectional	429 households, 267 women aged 15–49 years old.	N/A	Access to clean water, improved sanitation, and MHM resources.	Considered the needs of women.	No	Nearly 9 in 10 had water available when needed and 2/3 had water free from <i>E. coli</i> . A majority of pit latrines and septic tanks had never been emptied. 95% of women had a private place to wash and 98% had access to materials for managing their period.
Kwiringira et al. (2014)	Uganda	Cross-sectional	18 focus group discussions, and 16 informant interviews	N/A	Access to sanitation	Focused on outcomes in women and girls.	No	Women, children, and the elderly complained that latrines were not conveniently located, not clean, and not safe to use at night. Difficulties with keeping latrines clean due to communal use. Unclean latrines were abandoned.

*(Continued)*

TABLE 1 | Continued

References	Country	Study design	Sample size	Health component	WASH outcome	Gender outcome	Sex disaggregated	Conclusion
Lubon et al. (2018)	Nepal	Cross-sectional	16 interviews, three focus group discussions with 23 participants	No	perceptions of oral hygiene; frequency of oral hygiene utilization	Focused on cultural practices in pregnant women.	No	Women agreed that oral hygiene was important to prevent disease but had mixed views on the association between oral hygiene during pregnancy and healthy birth outcomes. Madhesi participants cleaned their teeth once a day using either a toothbrush and toothpaste or a teeth cleaning twig. Norms in the Pahadi women included brushing their teeth twice a day or more. A pertinent barrier was the inaccessibility of toothbrushes and toothpaste.
Magnusson and Bickenbach (2018)	Sierra Leone	Cross-sectional	139 lower-limb prosthetics patients	Access to healthcare services, and holistic measures of health.	Access to clean water	Compared gender differences.	No	Half of participants with prosthetics lacked access to clean water. Those in rural settings had significantly less access. Gender had an inconsistent effect on health-related measures.
Marinda et al. (2018)	Namibia	Cross-sectional	714 mother-child dyads; children aged 6–59 months old	Stunting in children aged 6–23 and 24–59 months.	Access to treated water	Considered maternal characteristics, and sex of the child.	No	Access to treated water reduced the risk of stunting by 2-fold. A mother's BMI increased the risk of stunting in infants 6–23 months old. The child's sex had no impact.
Nasr et al. (2013)	Malaysia	Cross-sectional	215 households, and 484 children	Soil-transmitted helminth infection; diarrhea.	Access to clean water, and frequency of handwashing	Assessed gender differences.	Yes	54.8% of respondents did not wash their hands before meals and 37.7% did not after defecation. Children who washed their hands before eating and after defecation experienced reduced rates of infection; hand washing before eating was higher in males (53.3 vs. 39.2% females) and also after defecation (71.1 vs. 56.0%).
Njuguna (2019)	Kenya	Retrospective longitudinal	2014: $N = 40, 300$ ; 2008: $N = 9,936$ , 2004: $N = 8,561$ , households	N/A	Access to improved sanitation	Compared gender differences.	No	Open defecation was reduced from 16.2% in 2003 to 9.9% in 2014. Pit latrines without a slab were most commonly used (37.9% in 2014). The gender of the household head predicted open defecation in 2003 and 2008, but not in 2014. It was not clear from the study which gender predicted open defecation.

(Continued)

TABLE 1 | Continued

References	Country	Study design	Sample size	Health component	WASH outcome	Gender outcome	Sex disaggregated	Conclusion
Oberoi et al. (2014)	India	Cross-sectional	250 patients	Perceptions of oral health on overall health	Frequency of oral hygiene utilization	Assessed gender differences	Yes	Eight in 10 used a toothbrush and toothpaste to clean their teeth, over half brushed their teeth once daily. Although not statistically significant, 64.1% of males found that oral hygiene was essential to their overall health compared to 56% of females. Twice as many more women cited cost as a barrier to oral hygiene. Women changed their toothbrush more infrequently.
Odetola and Fakorede (2018)	Nigeria	Cross-sectional	66 women	Satisfaction with perinatal care	Access to clean water	Attitudes of postpartum women.	No	80.3% of women felt that the hospital had adequate water and electricity. Inadequate water contributed to dissatisfaction.
O'Reilly and Louis (2014)	India	Mixed methods	607 households	N/A	Access to improved sanitation.	Assessed gender differences.	No	Shaming, fines, and withholding benefits were effective in getting households to build and use latrines. Women reported needing privacy to defecate, while men were less concerned.
Prado et al. (2019)	Ghana, Malawi, Burkina Faso	Prospective cohort	18-month-old children from Ghana ( $N = 1,039$ ), Malawi ( $N = 684$ ) and Burkina Faso ( $N = 1,504$ )	Infant stunting	Access to improved water	Considered maternal factors.	No	Improved household water, maternal education, maternal BMI, maternal height, and maternal hemoglobin levels were associated with reduced stunting.
Sato et al. (2016)	The Philippines	Cross-sectional	53 women	Assessed health needs, and presence of diarrhea following a typhoon.	Access to clean water and sanitation	Focused on pregnant women.	No	Pregnant women complained of diarrhea and leptospirosis due to the storm surge and unsanitary conditions. Women experienced abnormal pregnancy symptoms, and stress disorders.
Scott et al. (2018)	Zambia	Cross-sectional	167 women who were pregnant or with a child under 2 years old; 17 focus group discussions with 135 participants	N/A	Access to clean water	Pregnant women and new mothers were surveyed, focus group discussion answers between men and women were compared	Yes	There was limited access to water within maternity waiting homes. Respondents deemed it was culturally inappropriate to house pregnant women in waiting homes alongside families, travelers, or newly delivered mothers. Due to a lack of lighting and lockboxes, security was also a concern.

(Continued)

TABLE 1 | Continued

References	Country	Study design	Sample size	Health component	WASH outcome	Gender outcome	Sex disaggregated	Conclusion
Ugbomoiko et al. (2009)	Nigeria	Cross-sectional	440 children	Ascariasis infection	Access to a clean water source, improved sanitation	Compared gender differences.	No	Participants commonly defecated openly and retrieved water from boreholes or streams. Infection rates were similar between boys and girls. The water supply and type of sanitation had a strong effect on the prevalence of infection.
Winter et al. (2019)	Kenya	Cross-sectional	550 women	Previous history of diarrhea	Access to improved, secure, and private sanitation	Assessed women's WASH practices and outcomes.	No	Cultural practices influenced women's practices of when and how they accessed sanitary services. A lack of security and privacy were important concerns. Among women who used buckets and bags, a lack of privacy influenced their decision to dispose of urination/feeces at night. Having access to toilets was associated with an increased sense of privacy. A history of diarrhea did not influence sanitation practices.

included a lack of privacy, conveniently located latrines, as well as locks and security (Kwiringira et al., 2014; O'Reilly and Louis, 2014; Winter et al., 2019). In particular, a lack of privacy and security were related to women emptying bags and buckets at night, a behavior that can often increase the exposure of women to the threat of violence or sexual assault (Winter et al., 2019).

Generally, studies that compared access to sanitation between men and women found largely unremarkable gender differences (Ugbomoiko et al., 2009; Al-Delaimy et al., 2014; Alemu et al., 2017; Baker et al., 2018). However, one study in rural Ethiopia found that male-headed households were ~4-fold more likely to use household latrines than female-headed families (Aiemojoy et al., 2017). In addition, Njuguna (2019) showed that in Kenya, in 2004 and 2008, but not 2014, female-headed households were more likely to openly defecate than male-headed households. There is further evidence that girls had reduced access to improved hygienic practices. Nasr et al. (2013) comment that boys hand washed more frequently than girls, and Oberoi et al. demonstrated that girls less often changed their toothbrush and cited cost as a barrier (Oberoi et al., 2014).

A small fraction (6%) of studies focused on the role of MHM, where women reported a lack of proper MHM products, such as clean pads, in addition to private areas and an absence of water provisioning for cleaning and sanitation needs (Khan et al., 2017; Budhathoki et al., 2018; Davis et al., 2018). Davis et al. (2018) demonstrated how one in 10 students missed school due to menstruation, and this could, in part be attributed to menstrual stigma. However, the link between WASH resources in school and absenteeism was not definitive.

### Poor Access to WASH Resources Disproportionately Impacts Health Burdens Among Women and Girls, and Particularly Children

We found significant evidence of gender intersecting with WASH and health, with 33 of the 46 observational studies (72%) assessing a health component in relation to WASH (Figure 2). In total, 16 (48%) studies assessed childhood health and childhood infectious diseases, mainly centering on under-five mortality (15%), schistosomiasis/intestinal parasites (18%), and child-stunting (12%). Concretely, studies showed that maternal, or household access to clean water significantly reduced the risk of under-five mortality (Ahmed et al., 2016; Acheampong et al., 2017, 2018), child stunting (Akombi et al., 2017; Vos et al., 2017; Marinda et al., 2018), schistosomiasis (Atalabi et al., 2016; Donohue et al., 2017), and hookworm infections (Baker et al., 2018). Household piped water was one of the three stability factors needed to reduce HIV transmission for newborn infants (Doherty et al., 2007). Outside of the home, exposure to open water near schools increases the risk of schistosomiasis (Kapito-Tembo et al., 2009). Other aspects of WASH, including improved sanitation and handwashing, likewise reduced under-five mortality (Ahmed et al., 2016; Dendup et al., 2018), and schistosomiasis (Donohue et al., 2017), or acquiring other soil-transmitted helminths and parasites (Baker et al., 2018). In addition to the availability of sustainable WASH resources, maternal factors contributed to health burdens. Demographic

**TABLE 2 |** Intervention studies included in the analysis assessed for their WASH outcome, gender outcome, and inclusion of a health component.

References	Country	Study design	Sample size	Health component	WASH intervention	WASH outcome	Gender outcome	Sex disaggregated	Conclusion
Alzaher et al. (2018)	Saudi Arabia	Cluster randomized control trial	616 primary girl students	Considered school absences due to upper-respiratory tract infections.	1-h Arabic handwashing workshop.	Effect of handwashing	Focused on schoolgirls	No	School absence due to infection was lower in the two intervention implemented schools (0.54 and 1.02 cases per 100 school girls/day) than in the two control group schools (0.24 and 0.51 cases per 100 school girls/day). Statistics are not reported.
Cairncross et al. (2005)	India	Prospective cohort	515 women, 345 households	N/A	Health awareness campaign which included education classes to promote awareness of sustainable WASH practices	Frequency of handwashing; hygiene practices	Considered sex differences.	No	Handwashing practices were more significant than 50% in intervention implemented areas, compared with <10% in control areas. Nearly three-quarters of households with women remembered the education campaign, which is in contrast to only 18.5% of households with only men. The educational classes were associated with a 2-fold increase in handwashing practices by women.
Chaudhuri (2017)	France, Roma	Longitudinal Cross Sectional	30 women	Illness, including diarrhea, urinary tract infections, parasites, eye infection.	Community engagement intervention to design, construct and maintain toilets.	Access to MHM resources; access to private safe latrines.	Sampled women	No	After 18 months, the number of women reporting difficulties with their menstrual health needs dropped from 92 to 53%. Reported incidence of diarrhea reduced from 30 to 6%. 96 and 85% of women felt that privacy and safety were issues, respectively, and these frequencies dropped to 41 and 71% saying privacy and safety were issues.

(Continued)

TABLE 2 | Continued

References	Country	Study design	Sample size	Health component	WASH intervention	WASH outcome	Gender outcome	Sex disaggregated	Conclusion
Huq et al. (2010)	Matlab, Bangladesh	Cohort study	7,233 village women collecting water daily	Incidence of cholera-related hospital visitations	A simple sari water filtering method	Access to clean water	Focused on women	No fetching water.	31% of the village women continued to use the water filter 5 years after the intervention. The incidence of cholera hospital visitations was reduced by 25% in the filter group, although this was not significant.
Katsivo et al. (1993)	Kenya	Cross-sectional study	203 head of households	Knowledge of schistosomiasis transmission	Handpumps, shallow wells, pit latrines were installed at 6 well-sites.	Access to clean water, and sanitation	Perceptions of the male and female head of households were considered	No	Following the intervention, 82% head of households believed their children appeared healthier as a result of the potable water and bathrooms near the well sites. Almost everyone (99%) believed that the intervention had controlled schistosomiasis. More than 90% knew the cause of schistosomiasis, how it is transmitted, its treatment, and how to prevent and control it.
Magnin et al. (2018)	Madagascar	Cross-sectional	74 mothers	Malnutrition and broad child health outcomes.	35-days educational program on children's nutrition, WASH, and health.	Level of hygiene education; frequency of handwashing; access to clean water.	The intervention focused on mothers of children.	No	The WASH component of the intervention was cited by participants as being successful and improved the children's health.
Nyoka et al. (2017)	Northwest Kenya, (Kakuma refugee camp),	Prospective longitudinal study	Post-implementation of Dinka and Somali Refugees with 6–10 participants each.	N/A	Implementation of new sanitation system	Access to improved sanitation	Specifically considered women's needs.	No	For Dinka participants, sanitation at the camp was as an improvement. Using latrines was better than open defecation. Somali participants did not prefer latrines. Some women with genital mutilation could not use toilets easily

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TABLE 2 | Continued

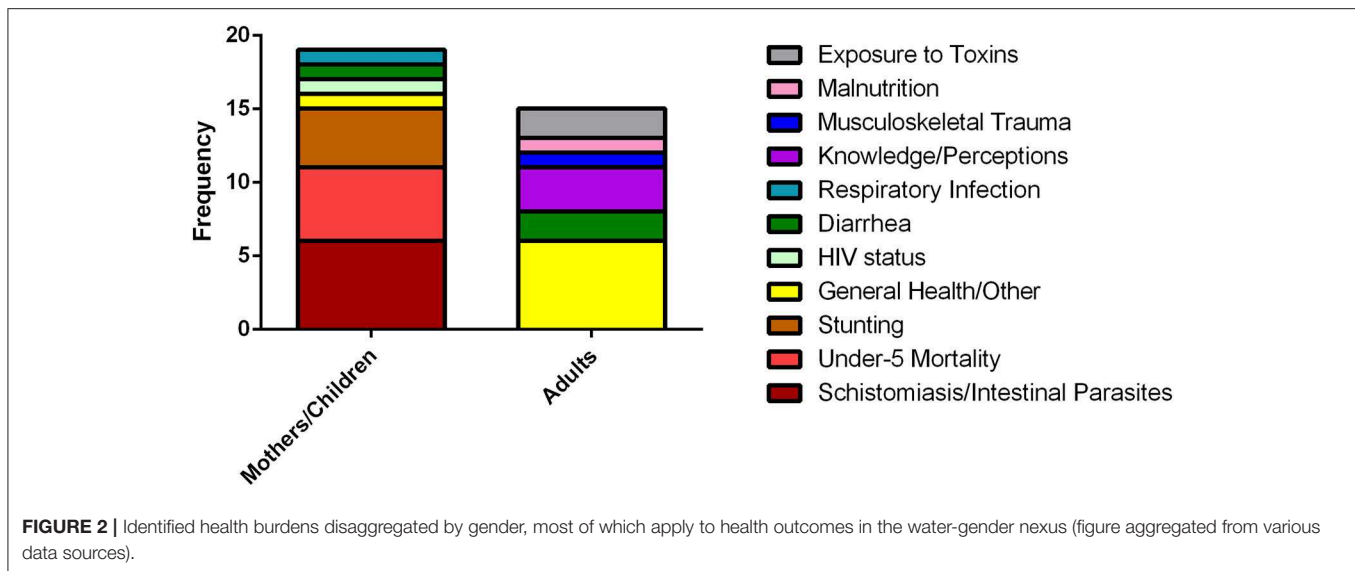
References	Country	Study design	Sample size	Health component	WASH intervention	WASH outcome	Gender outcome	Sex disaggregated	Conclusion
Pickering et al. (2017)	Bunoma, Kakamega, Vihiga, and Busia, Kenya, (rural population, pregnant women)	Cross-sectional	499 households at 6 months, 531 households at 18 months, and 7,691 household at 24–36 months	N/A	A program distributed 1 million water-filters.	Access to improved water sources	Sampled households with pregnant women	No	Microbial water quality was improved in filtered stored drinking water when collected at 24–26 months after filter distribution; however, fecal indicator bacteria <i>Escherichia coli</i> remained present. 19% of households reported retained filter usage after 2–3 years.
Rose et al. (2006)	Vellore, Tamil Nadu.	Prospective cohort study	200 children	Incidence of diarrhea	Children were provided with solar disinfected water	Clean water	Mothers were interviewed for trial design and feasibility.	No	Solar treated water reduced the incidence of diarrhea by 40%. Mothers believed the treatment to be feasible.
West et al. (1996)	Kongwa, Tanzania	A randomized, longitudinal study	240 households, a total of 1,168 participants	Risk of and frequency of severe trachoma	Face-washing intervention	Access to a clean water, and hygiene resources.	Sex distribution of children with trachoma, and prevalence of episodes of severe trachoma by sex, and a risk factor for severe trachoma.	Yes	A two-fold increase in the risk of constant, severe trachoma in females vs. males; children with a clean face had a 40% decrease risk of having severe trachoma at 1 year follow-up, children with severe trachoma decreased from 31 to 11% and at every time point, females had more severe trachoma.
Williams et al. (2015)	Haiti	Cross-sectional study	17 focus-group discussions	Frequency of cholera and diarrhea	Health messages on sustainable WASH practices	Access to clean water, improved sanitation	Considered women's focus group discussions	No	Focused group discussions revealed that both cholera and diarrhea were observed. Members reported improved WASH practices following the messages, and diarrhea was reportedly reduced. A lack of latrines was the most commonly cited need. There was a marked gender difference, generally, women were more informed on improved water and sanitation practices.

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TABLE 2 | Continued

References	Country	Study design	Sample size	Health component	WASH intervention	WASH outcome	Gender outcome	Sex disaggregated	Conclusion
Wilson and Chandler (1993)	Lombok, Indonesia	Cross-sectional study	57 mothers, and 102 children	Frequency of diarrhea	Handwashing intervention providing education and soap.	Access to hygiene resources; frequency of handwashing	Conducted in mothers	No	2 years after the intervention, 8 in 10 mothers retained using hand soap. Diarrhea frequency decreased by 90%. Before the intervention, zero mothers washed theirs or their children's hands with soap after defecation or before eating. Yet, after the intervention, 56 reported always doing so following defecation, and 94% claimed to do so before eating.
Yeasmin et al. (2017)	Bangladesh	Longitudinal	24 adults for post-interviews	N/A	A waste bin and informational signs to indicate how to use the latrine/waste bin	Access to improved sanitation, MHM;	Considered gender differences	No	In general, the waste bins were well-accepted and were reported to reduce blockages. Some males indicated disgust with menstrual health rags in the trash bins was a barrier to their use by women. Women likewise felt disgusted when using waste bins. Women possessed cultural beliefs that menstrual rags could serve as vehicles to spread disease to men.



factors, including the mother's BMI (Marinda et al., 2018; Prado et al., 2019), age (Dendup et al., 2018), education level (Nasr et al., 2013; Hasan and Richardson, 2017; Akachi et al., 2018; Prado et al., 2019), and lack of employment (Atalabi et al., 2016) were all found to increase the risk of disease in children.

In assessing whether women and girls were at higher risk for health burdens, most studies focused on children determining that boys were at greater risk for contracting both schistosomiasis (Kapito-Tembo et al., 2009; Ugbomoiko et al., 2009; Atalabi et al., 2016; Donohue et al., 2017) and hookworm infections (Baker et al., 2018) as well as stunting (Akombi et al., 2017) which is in line with a well-documented propensity for increased mortality among male children (World Health Organization, 2011). A single study directly analyzed the effect of gender on the frequency of waterborne diseases in adults, and found no gender differences (Al-Delaimy et al., 2014). However, numerous studies demonstrated that women's role as the primary water purveyor exposed them to multiple health risks. Women are at an increased risk of musculoskeletal disorders as a result of carrying water long-term and across long distances (Geere et al., 2018). Interestingly, males, but not females who fetched water >15 min, prioritized improving access to water over improving access to health services (Hunter, 2006). Women who fetched water from a drill pipe may also be at increased exposure to toxins, including lead as the blood of first-trimester pregnant women was recorded to have elevated levels of toxin lead (Guy et al., 2018). Also, how unclean water exposes households and adults more generally to toxins, such as Dichlorodiphenyldichloroethylene (DDE) and Dichloroduphenyltrichloroethane (DDT) is documented by Gaspar et al. (2017). New mothers and pregnant women, in particular may represent a vulnerable population. For example, religious, new mothers who were fasting and did not have access to improved water or sanitation were more likely to be underweight (Desalegn et al., 2018). Furthermore, pregnant women who experienced a natural disaster reported a lack of access to basic water and maternal care which added physical and psychological stress (Sato et al., 2016).

A summary comparison of key gender, health and water differences from analyzed observational studies can be found in **Table 3**.

### Both Infrastructural and Educational Interventions Are Successful in Reducing WASH Inequities and Improving Health Outcomes

To assess whether identified water-gender and health inequities can be addressed by currently administered interventions, we aimed to identify best practices themes from WASH interventions (**Table 2**). Of the 13 interventional studies included, eight examined water access, eight assessed sanitation, six assessed hygiene, and one assessed MHM. Interventions were equally split between providing WASH education ( $N = 8$ ) or providing physical infrastructural improvements ( $N = 9$ ). The majority of studies ( $N = 9$ ) considered how WASH interventions could improve health impacts.

Infrastructural interventions that improved water accessibility demonstrated mixed results for long-term benefits. Filtration systems provided to women were retained by 19 to 31% after a 2–5 years follow-up (Huq et al., 2010; Pickering et al., 2017). Similarly, the use of filters corresponded to small improvements in water quality (Huq et al., 2010), and a minor reduction in the incidence of cholera (Pickering et al., 2017). However, there remained a significant depreciation in the long-term usage of the interventions (Huq et al., 2010; Pickering et al., 2017). An intervention that provided mothers with treated water was successful in reducing diarrhea in school children by 40% and was considered a feasible solution by the participating mothers (Rose et al., 2006). Hand pumps were linked with overall healthier looking children (Katsivo et al., 1993). Furthermore, a comprehensive intervention which combined hand-pumps, latrines, and hygiene education demonstrated significant success after a 7-years follow-up, drastically increasing the number of households using improved WASH practices, reducing bacteria on the hands of mothers, and consequently the incidence of diarrhea in children (Hoque et al., 1996).

**TABLE 3** | A summary of key gender differences in access to WASH and health outcomes identified from assessed observational studies.

Indicate a WASH or Health impact on women		Indicate no gender difference
A lack of clean water negatively impact women and girl's quality of life	Doherty et al., 2007; Bornman et al., 2012; Sato et al., 2016; Gaspar et al., 2017; Vos et al., 2017; Angoua et al., 2018; Prado et al., 2019	
Women may have reduced water security	Bisung and Elliott, 2018	
Women are the primary purveyors of water	Hunter, 2006; Bornman et al., 2012; Holvoet et al., 2016; Geere et al., 2018	
<b>Sanitation and Hygiene</b>		
Women lack access to sustainable sanitation and hygiene facilities and resources.	Kwiringira et al., 2014; Sato et al., 2016; Khan et al., 2017; Aluko et al., 2018; Angoua et al., 2018; Budhathoki et al., 2018; Dendup et al., 2018; Desalegn et al., 2018; Lubon et al., 2018; Winter et al., 2019	Gender differences in accessing a latrine were largely unremarkable.
Women and girls were burdened by latrines which lacked privacy and security.	Kwiringira et al., 2014; O'Reilly and Louis, 2014; Winter et al., 2019	Ugbomoiko et al., 2009; Al-Delaimy et al., 2014; Alemu et al., 2017; Baker et al., 2018
Male-headed households were more likely to have a household latrine.	Aiemjoy et al., 2017; Njuguna, 2019	
Girls had less access than boys to hand and oral hygiene	Nasr et al., 2013; Oberoi et al., 2014	
Women and girls lack access to MHM	Khan et al., 2017; Budhathoki et al., 2018; Davis et al., 2018	
<b>Gender WASH and Health</b>		
Maternal and household access to improved WASH reduced the risk for childhood infections, stunting, and mortality.	Doherty et al., 2007; Kapito-Tembo et al., 2009; Ahmed et al., 2016; Atalabi et al., 2016; Acheampong et al., 2017, 2018; Akombi et al., 2017; Donohue et al., 2017; Vos et al., 2017; Baker et al., 2018; Marinda et al., 2018	
Maternal socioeconomic, demographic, and health indicators reduce the risk for childhood disease.	Nasr et al., 2013; Atalabi et al., 2016; Hasan and Richardson, 2017; Akachi et al., 2018; Dendup et al., 2018; Marinda et al., 2018; Prado et al., 2019	
Boys were at greater risk than girls for childhood disease.	Kapito-Tembo et al., 2009; Ugbomoiko et al., 2009; Atalabi et al., 2016; Akombi et al., 2017; Donohue et al., 2017; Baker et al., 2018	
Women's role as the primary water purveyor increased the risk for musculoskeletal disorders and facilitated exposure to waterborne toxins, including heavy metals (e.g., lead), Dichlorodiphenyldichloroethylene (DDE) and Dichloroduphenyltrichloroethane (DDT).	Gaspar et al., 2017; Geere et al., 2018; Guy et al., 2018	Among adults, sex did no impact the risk for disease.

Interventions that focused on the construction of latrines and toilets were successful in reducing the incidence of diarrhea (Chaudhuri, 2017), improving overall health (Katsivo et al., 1993), and providing more women with the privacy and safety necessary to attend to their menstrual health needs (Chaudhuri, 2017). However, while generally well-tolerated (Nyoka et al., 2017; Yeasmin et al., 2017), latrines and waste bins are associated with challenges. For example, both men and women reported feelings of disgust with menstrual rags being placed in waste bins (Yeasmin et al., 2017). Furthermore, women affected by genital mutilations had issues using latrines (Nyoka et al., 2017). As well, culture played a

role in women preferring to openly defecate instead of using latrines (Nyoka et al., 2017). Hygiene-related interventions were likewise successful at alleviating disease. A face washing intervention reduced the incidence of trachoma (West et al., 1996), which had a reported higher incidence in girls than boys. Providing mothers with soap reduced diarrhea by 90% in children, as well as respiratory tract infections in school-children (Alzahr et al., 2018), and improved long-term hand hygienic practices (Wilson and Chandler, 1993; Cairncross et al., 2005).

In addition to capacity, education represents a crucial component for improving WASH and has been incorporated

as one branch of successful multifactorial interventions, for example, to overcome cultural apprehensions and misconceptions with using latrines (Yeasmin et al., 2017). Qualitative assessments of educational interventions suggest that education can reduce the incidence of diarrhea (Williams et al., 2015) and improve overall health (Magnin et al., 2018). Evidence that women were better than men at learning sustainable WASH practices through educational interventions has also been reported (Cairncross et al., 2005; Williams et al., 2015).

### Assessment of Risk of Bias

In general, the included studies showed evidence for lower levels of bias. Across the 52 assessed cross-sectional studies, 41 (79%) were definitely or probably representative of the target population (**Supplemental Table 1**). The largest issues surrounded the reporting of participant non-response rates which was not reported by 15 studies (29%). To our assessment, all of the six included cohort studies likewise exhibited lower levels of bias (**Supplemental Table 2**). Finally, one study deployed a randomized control trial to assess the effectiveness of a school intervention, which, with the exception of evidence of blinding, exhibited lower levels of bias (**Supplemental Table 3**).

## DISCUSSION

### Summary of the Main Findings

This systematic review assessed WASH-related challenges faced by women and girls and further established a clear link whereby gendered WASH inequities interconnect with health outcomes, thereby establishing the “water-gender-health” nexus. We found some indication that women may have less access to clean water (Bisung and Elliott, 2018); however, few studies have directly interrogated this question. Regardless, women and girls typically served as the main water purveyors, a role which increased their risk for musculoskeletal trauma (Geere et al., 2018), and exposure to waterborne toxins (Gaspar et al., 2017; Guy et al., 2018). Additionally, a lack of latrines that are safe, secure, and private represents a major engendered barrier. The absence of such facilities forces women and girls to avoid practicing sustainable sanitation, hygiene, and MHM due to a fear of violence, or as a result of stigmatization (Kwiringira et al., 2014; Khan et al., 2017; Budhathoki et al., 2018; Davis et al., 2018; Winter et al., 2019). Poor WASH, in general, was linked to a multitude of health burdens, and particularly childhood diseases, including schistosomiasis, under-5 mortality, and stunting (Ahmed et al., 2016; Atalabi et al., 2016; Acheampong et al., 2017, 2018; Akombi et al., 2017; Donohue et al., 2017; Vos et al., 2017; Baker et al., 2018; Marinda et al., 2018). WASH infrastructural and educational interventions in general showed promise in reducing inequities in the water-gender and related health outcome; however, issues surrounding long-term adoption reduced efficacy (Huq et al., 2010; Pickering et al., 2017).

### Improving WASH Is a Critical Agent for Women’s Health and Empowerment

Without explicitly searching for health-related outcomes, our search uncovered a significant overlap between WASH

inequities among women and health, thereby linking the water-gender nexus with health. In support of our analysis, global reports have recognized that women and girls experience occupational hazards for waterborne diseases as a result of exposure to contaminated water and soils (World Health Organization, 2011). Irrespective of gender, the SDG six synthesis report (2018) has recognized handwashing with soap and water as a top priority for reducing disease transmission; however, gender disparities largely have not been recognized (United Nations, 2018).

Health burdens can significantly reduce human agency, for example, by reducing income and employment (Alam and Mahal, 2014). Considering that in low-resource settings women have reduced agency to make healthcare decisions, the impacts of disease and disability are likely to be further magnified (Osamor and Grady, 2016). Thus, addressing inequities in the water-gender nexus will have wider-reaching network effects, including supporting women’s health, and by extension their empowerment, as outlined in various SDG five targets, including 5.c (i.e., adopt and strengthen sound policies and enforceable legislation for the promotion of gender equality and the empowerment of all women and girls at all levels). In addition, our analysis highlights a clear linkage between gender equitable access to WASH, and SDG 3.2 which aims to, by 2030, in all countries, end preventable deaths of newborns and children under 5 years of age, reduce neonatal mortality to at least as low as 12 per 1,000 live births, and to reduce under-5 mortality to at least as low as 25 per 1,000 live births. Thus, an enhanced understanding of interlinkages between water, gender, and health are increasingly relevant to, through a coordinated and integrated effort, achieving the SDGs.

### MHM Is a Gap in the Sustainable Development Goals

Surprisingly, our analysis identified only a limited number of studies which addressed MHM. However, given that sustainability, and linkages with the SDGs was an explicit search term, the limited number of identified papers which assessed MHM practices perhaps reflects a more significant issue that MHM is not included clearly as an indicator within the SDGs portfolio (Anjum et al., 2019). The 2018 SDG 6 Synthesis Report more broadly describes how having access to safe drinking water and WASH in schools can improve school attendance by allowing girls to meet their MHM needs (United Nations, 2018). Likewise, other systematic reviews have concretely shown the implications of MHM on promoting education and good health among adolescent girls (Sommer et al., 2016). This principle can be expanded beyond schooling and into the workplace. In Bangladesh, where four out of five factory workers are women, more than two thirds lose 6 days of work in a month because of a lack of safe places to change their menstrual pads/cloths and the absence of disposal sites. Therefore, it is quite evident that addressing MHM needs is connected with women’s access/capacity to gain education, employment, and financial capacity.

Recognizing this need, in 2012, Kenya launched the Sanitary Towel program to distribute sanitary towels to girls who attended

school to support their education and to promote health and well-being. International Organizations have recognized the importance of MHM, including the United Nations Office for Coordination of Humanitarian Affairs (UN-OCHA), through forming humanitarian response plans, and these are part of a broader goal of addressing WASH needs.

### Education and Long-Term Uptake Are Critical for Successful Interventions

Our analysis of interventions to improve WASH can be successful in reducing both WASH inequities and disease; however, a focus is needed to ensure their long-term maintenance and usage. To this end, some reports indicated that women had greater levels of WASH knowledge and were better at retaining WASH-related education (Cairncross et al., 2005; Williams et al., 2015). This presents empowering women with WASH-related education as a simple, and feasible component for implementing successful interventions in the context of health and sanitation-related challenges. This strategy has been embodied within SDG 6.b which calls for supporting and strengthening the participation of local communities in improving water and sanitation management. Our analysis supports global calls for gender mainstreaming and addressing gender inequalities in the water and WASH sectors.

### A Dearth of Sex-Disaggregated and Unbiased Assessments of Sustainable WASH Accessibility

In clarifying the reliability of our identified findings, a majority of studies exhibited a lower risk of bias, often deploying appropriate sampling strategies. However, only half of studies directly compared WASH outcomes between genders, and <10% reported at least some gender-disaggregated data. Consequently, while we report examples of gender and WASH deficiencies, it is difficult to understand how women's access to WASH services, and corresponding health effects, differ from similarly situated men.

Recognizing this problem, in 2014, the UNESCO World Water Assessment Programme (WWAP) spearheaded the formation of the "Gender and Water Toolkit" which focused on understanding and furthering the gender-water-related research and investigation through the development of new sex-disaggregated indicators to more granularly enumerate gender-disparities related to WASH. As stated by the UNESCO/WWAP, *"it is not an exaggeration to say there is virtually no sex-disaggregated data on water and sanitation sectors collected by the main international agencies and groups responsible for global data compilation."* The 2nd edition launched in 2019 incorporates 105 indicators in 10 different topics related to the SDGs which includes water governance, safe drinking water, sanitation and hygiene, knowledge resources, transboundary water management, water for agricultural uses, water for industry and enterprise, and human rights-based water resource management. Future investigations which explore the water-gender nexus should consider gender differences and sex-disaggregated data in their WASH analyses to better identify women specific barriers, as well as to elevate problems common to all gender groups.

### Water, Gender, and Health Interconnect More Broadly With Other Goals Toward Sustainable Development

The SDG 6 synthesis reports that modest progress has been made to meet the targets of the 2030 Agenda; however, a specific focus on gender issues is lacking. All 17 SDGs are explicitly and implicitly related to water, while only a fifth of SDG indicators refer to gender or sex. Nevertheless, some of the major themes encapsulated in this review directly relate to established SDGs. For example, target 6.2 that highlights the importance of hygiene and calls for special attention to the needs of women and girls. Likewise, target 3.9 calls for substantial reduction of the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination, hazards which we contend represent occupational hazards for women and girls. It is also important to recognize that the interconnections that occur among SDG three, five, and six also extend to other SDGs, including; labor markets (SDG 8), political participation (SDG 10), poverty (SDG 1), peaceful and inclusive societies (SDG 16), among others. Future work should continue to elucidate these interactions.

### Moving Forward: Addressing Stigma and Promoting Gender Mainstreaming

Gender-inequity is in part facilitated by stigma, engendered cultural norms, and a societal power imbalance. Stigma actively prevents women and girls from developing healthy habits (e.g., using soap and water or from using latrines (O'Reilly and Louis, 2014; Yeasmin et al., 2017; Winter et al., 2019). However, more than restricting access to WASH, stigma becomes an entrenched psyche, which actively promotes mental and physical distress and its pernicious effects can be readily seen with regard to MHM (Sommer et al., 2015a). For instance, girls' emotions surrounding MHM can include sadness, stress/anxiety, physical discomfort, feeling dirty, and shame, and consequently, engendered needs are often silenced (McMahon et al., 2011; Naeem et al., 2015). The stigmatization of menstruation can even result in women and girls exchanging "their bodies" for money in order to access resources for menstrual pads (Mason et al., 2013). As a result, even when capacity is available, stigma can undermine development efforts, and must be actively addressed. While methods to address stigma remain in their infancy, especially in LMICs, interventions are needed to raise awareness on the importance of engendered WASH priorities, to ensure that the needs of women and girls are underscored.

Reducing gender inequities will also inevitably require women to have a more prominent platform to advocate for the remediation of nuanced gender-barriers (Morna, 2000). In this respect, like others [Kholif and Elfarouk, 2014; Leahy et al., 2017; Dery et al., 2019; World Water Assessment Programme (UNESCO WWAP), 2019], we advocate for gender-mainstreaming efforts when addressing WASH inequities. From ours and other's work it is clear that women occupy important WASH roles within households, both with fetching, storing, and using water (e.g., cleaning, cooking, washing, etc.) (Morna, 2000). Therefore, women and girls possess a particularly germane perspective which is needed to ensure that engendered WASH-related barriers are elevated and considered by policymakers and

decisionmakers. Including female perspectives may help elevate gender-based priorities (Dery et al., 2019), such as that when latrines are constructed, they include locks, are private, and are well-lit, in order to promote safety and therein increase access for women and girls. Thus, ensuring that a gendered perspective is included when developing capacity is essential to reducing engendered WASH inequities at scale.

Simultaneously, elevating women to leadership positions may aid in reducing cultural engendered power imbalances which actively suppress the human development of women and girls. Women and girls remain particularly disenfranchised, for example, due to their role as water purveyors and homemakers, gender roles which exacerbate the risk for health burdens (Sommer et al., 2015b; Gaspar et al., 2017; Geere et al., 2018; Guy et al., 2018), and sexual assault. Improving the status of women through gender mainstreaming represents an important first step in reducing the impact of cultural norms (UN Women, 2017). However, invariably, broader active efforts are needed to alter social behavior. While we recognize that behavioral change is a gradual process, sustainability and the empowerment of women will necessarily require efforts to break engendered cultural norms, and support the empowerment of women—critical steps to promote women's human development, and more broadly, sustainable development (Dery et al., 2019).

## Strengths and Limitations of the Systematic Review

This analysis broadly combined qualitative investigation on the nuanced experiences of women with quantitative assessments on accessing sustainable WASH. While this afforded us a broad perspective on the array of WASH inequities faced by women and girls, we cannot effectively describe the magnitude of WASH deficiencies. As well, we did not exclude studies with high bias, and this limits the generalizability of our findings. We did not explicitly include keywords for health in our search strategy, which serves as a kind of prevalence calculation in order to support broad interlinkages within the literature between gender, water, and health may limit the number of health-related studies identified. However, the use of the MEDLINE database likely adds a bias toward journal articles which consider health outcomes. As such, our findings should be viewed as a basis to enhance the understanding of the water-gender nexus, particularly within the sphere of related health outcomes. Finally, the search method was restricted to English, and thus, this is acknowledged as a limitation.

## CONCLUSIONS

Major manifestations of the water-gender nexus include that women are burdened as a result of their role as water purveyors,

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a lack of private and secure latrines disproportionately impact women, and that women have less access to sustainable hygiene resources. In particular, there is a strong need for increasing MHM resources which are instrumental in supporting women's health, education, and human development. In general, we found a strong intersection between the water-gender nexus and health outcomes—the water-gender-health nexus. These include occupational health risks as a result of chronically carrying water and being exposed to contaminated water, as well as risks for infection due to poor sanitation and hygiene. Moreover, poor WASH practices among mothers are strongly linked with childhood diseases. Interventions were generally effective in reducing WASH inequities and poor health outcomes. To better understand the water-gender and health interlinkages, there is a clear need for increased efforts toward sex-disaggregated data collection, as well as incorporating direct gender comparisons with respect to accessing and monitoring WASH services, and their associated health outcomes. This analysis supports the conjecture that addressing the water-gender nexus will help manage disease burdens and have a more significant impact on achieving the targets of SDGs three, five, and six in tandem.

## DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

## AUTHOR CONTRIBUTIONS

PP and NN with contributions from MM designed the research idea and the basis of the content for the manuscript. PP conducted data extraction, analyzed the data, and wrote the manuscript. PP, NN, and MM revised, and edited the manuscript.

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## SUPPLEMENTARY MATERIAL

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**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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