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Influences on water source selection and use among women in rural Odisha, India

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Introduction: Water is a crucial resource for many household functions, including drinking, cooking, bathing, and washing clothes. Globally, women bear the burden of water collection in households without piped water, as well as responsibility for household chores that require water. Carrying water has a number of health and safety risks, and women often rely on multiple water sources. The goal of this study is to understand how women in rural Odisha, India, an area with high coverage of improved water sources, make decisions on where to collect water.

Methods: This is a grounded-theory, secondary analysis of qualitative data collected from 69 women across life stages in eight villages in rural Odisha. Women were asked about their concerns and difficulties related to water and probed for details in a variety of contexts, including at night, during monsoon season, and during pregnancy.

Results: Women's standards for water quality vary depending on the planned use of the water. They report a willingness to travel long distances to collect better tasting water for cooking and drinking. When washing clothes, they often prefer a larger body of water. Bathing or washing menstrual cloths requires privacy. Their ability to access water varies based on individual characteristics such as: life stage, as recently married women have less freedom of movement than older women; health status, as older women report difficulties carrying water long distances; cyclical patterns such as seasonality, as certain sources are inaccessible during monsoon season; and characteristics of the water and the source itself, which encompasses distance, perceived quality, and privacy, among others.

Discussion: These findings indicate that public health interventions and surveys that monitor household water should not only consider the presence of a water source on the premises, but should also include multiple source use and consideration of individual members of households and the time of data collection, as water sources may not be equally available or acceptable to all household members at all times. In climate-sensitive areas, multiple water source use may become increasingly necessary as a response to changes in the environment, and should be considered in climate resilience interventions.

KEYWORDS

multiple water sources, water quality, life stage, menstruation, monitoring, climate change, decision-making

1. Introduction

Access to safe, accessible, acceptable, and affordable drinking water that is available when needed, is a human right and critical for health ([Resolution 64/292, 2010](#)). Research has shown that compromised water quality and access is associated with negative physical health outcomes, such as diarrheal ([GBD Diarrhoeal Diseases Collaborators, 2017](#); [Wolf et al., 2018, 2022](#); [Pruss-Ustun et al., 2019](#)) and respiratory diseases ([Hennessy et al., 2008](#); [Ashraf et al., 2020](#)) and

musculoskeletal injury, and negative mental health outcomes, such as anxiety (Brewis et al., 2019), psychological distress (Stevenson et al., 2012, 2016), and depression (Cooper-Vince et al., 2018; Brewis et al., 2019; Mushavi et al., 2020). Yet despite the need for and right to water, progress toward Sustainable Development Goal (SDG) target 6.1, which aims to “achieve universal and equitable access to safe and affordable drinking water for all,” (UN General Assembly, 2015) is lagging. Notably, data from 2020 reveal that two billion people lacked access to safely managed drinking water services globally (JMP, 2021).

It remains unclear how many people lack access to water for non-drinking purposes, such as personal and domestic hygiene, cooking, and homestead gardens, and where that water is accessed. A World Health Organization review of water quantity needs states that an individual needs an average of 50 L of water a day for drinking, cooking, and personal and food hygiene; only 5.3 L are allocated to drinking water in this estimate (Howard et al., 2020). An emerging body of research has reported that households access multiple water sources to meet household water needs, including in areas where households have access to improved drinking water sources (Daly et al., 2021). In Pacific Island countries, Elliott et al. (2017) found that 91% of households used more than one source, frequently choosing different sources for drinking and cooking than for handwashing or bathing. In Ghana, Chew et al. (2019) found that cultural norms that prevented people from accessing sources at specific times as well as the physical burden of collection from certain sources influenced women to collect water from multiple sources. Several studies have found multiple water source use to be influenced by seasonality, which can influence the quantity and perceived quality of water at a preferred source (Shaheed et al., 2014; Elliott et al., 2017; Chew et al., 2019; Daly et al., 2021). There is a need for greater understanding of multiple water source use, including what sources are used, and for what purposes.

Understanding how women select water sources for different uses is particularly important because they are typically responsible for water fetching globally (Sorenson et al., 2011; Graham et al., 2016). Water fetching incurs safety risks (Varickanickal et al., 2019), can be physically burdensome (Sahoo et al., 2015; Varickanickal et al., 2019), and is associated with musculoskeletal problems (Geere et al., 2018), all of which may influence where water is accessed and collected. Further, women are frequently the decision-makers over household water management, including both collection and use, decisions that may be constrained by water quantity (Wutich and Ragsdale, 2008), time required for fetching (James et al., 2002; Kher et al., 2015), distance to the source (Varickanickal et al., 2019), cost (Wutich and Ragsdale, 2008), and the need for childcare (Varickanickal et al., 2019). Multiple studies in South Asia have found that decisions surrounding household chore allocation, including water collection, are governed by senior women in the household (James et al., 2002; Sultana, 2009; Jha, 2012; Clement and Karki, 2018), often to the detriment of younger women, who report their movement outside the house and ability to fetch water from preferred sources to be limited as a result of cultural traditions or restrictions (Jha, 2012; Mehta and Saxena, 2015; MacRae et al., 2019). As such, in addition to understanding which water sources are used, it is also critical to understand what factors influence women’s decisions to use various sources.

While research documenting and describing multiple water source use is growing, global monitoring focuses on primary sources for drinking water only; it does not address other needs for water

at the household level or sources that are non-primary except for households that report their “main” source as packaged/bottled water (JMP, 2018). There is a need for global health researchers and practitioners to understand how and why various water sources are accessed, both to mitigate water-related risks to health and wellbeing beyond those linked to drinking water and to ensure sufficient quantity and acceptable quality of water for all needs.

The aim of this study is to understand water source selection and use among women in rural Odisha, India and to explore the reasons for their decision-making. In 2016, shortly after this study was conducted, India’s National Family Health Survey found that 87.5% of households in rural Odisha had an improved drinking water source (International Institute for Population Sciences, 2016); data collected from 2020 to 2021 show an increase in coverage to 90.8% (International Institute for Population Sciences, 2021). Jal Jeevan, a piped water scheme to extend access to piped water to all households in rural Odisha communities by 2024 is currently underway (Department of Drinking Water and Sanitation, and Ministry of Jalshakti). Understanding behaviors surrounding multiple water source use in Odisha, an area with high coverage of improved water sources at the time of the study, is crucial as this piped water scheme moves forward, particularly if desired outcomes related to health and wellbeing are to be achieved.

2. Methods

2.1. Study design and setting

This is a secondary analysis of qualitative data from a parent study that used a sequential mixed-methods design (Creswell and Clark, 2017) to create measures to understand and assess sanitation (Caruso et al., 2017a,b) and menstruation (MacRae et al., 2019; Caruso et al., 2020) insecurity and practices in villages that had been included in a trial evaluating the impact of a sanitation intervention on various health outcomes (Clasen et al., 2014). The qualitative data used for this secondary analysis were collected in eight rural villages in Puri district of Odisha, India. While the parent study focused on sanitation, a specific line of questioning was asked about water to initiate the interviews given the need for water in these communities for sanitation purposes, including post-defecation cleansing and flushing toilets, among other needs. The decision to carry out this secondary analysis emerged during the preliminary analyses focused on sanitation and menstruation as we found women noting the various sources of water that they use despite the widespread coverage of improved water in the area. Specifically, an estimated 94% of rural households in Puri were reported to have had access to an improved drinking water source at the time of data collection (International Institute for Population Sciences, 2016). This analysis sought to examine how women selected water sources in an area with a high coverage of improved water sources.

2.2. Study population and eligibility

Study participants were women aged 18 years or older residing in the study villages. Only one woman per household was eligible. Women were ineligible if they could not communicate verbally in Oriya or understand the purpose of the study. Participants were

initially recruited via community gatekeepers who were familiar with the characteristics of local residents and could identify eligible women to participate. In addition, snowball sampling was used to find additional participants. Specifically, the study team asked participants if they knew of any other women who fit the eligibility criteria and, if so, where to find them. The study team went looking for the additional participants identified using directions offered.

2.3. Recruitment

We purposively recruited 69 women from four life stages: (1) unmarried women (UMW; $n = 17$) since young women living with their parents commonly fetch water for the household; (2) women who had recently married in the previous 3 years (RMW; $n = 12$) as these women often have limited independent freedom of movement outside the home so depend on others to provide water for them (Joshi et al., 2011; Routray et al., 2015); (3) women who have been married for longer than 3 years (MW; $n = 21$), since they typically have greater social status in the household and more freedom of movement outside the house than RMW (Medhi, 2002); and (4) women older than 49 years (OW; $n = 19$), who may experience unique water challenges related to aging, such as difficulty walking or carrying heavy loads (Singh et al., 2013), which could make them dependent on others for their water needs. Women over 49 years are also under-represented in national surveys about water, sanitation, and hygiene (WASH). We recruited women at each life stage from each study village.

2.4. Data collection

Data were collected from March to April 2014 via in-depth interviews. Interviews were conducted in the local language (Oriya), by two female interviewers fluent in both Oriya and English, who were part of research team for the parent study. The interviewers were experienced in qualitative research and participated in a multi-day training on qualitative data collection which included piloting the interview guide.

Prior to each interview, demographic characteristics of participants were recorded, including their level of education, age, marital status, number of children, household water sources, sanitation facilities and practices, and menstruation resources and practices. The semi-structured interview guide for the parent study included five topics: water use, urination, defecation, menstruation, and hygiene practices. This secondary analysis focuses on the data related to water use. Questions about water use were the least sensitive and were asked first to develop rapport with participants. Participants were asked to describe “concerns and difficulties you or women like you in this community face related to water use.” Interviewers probed women to continue sharing concerns until nothing else came to mind. Once general concerns were shared, interviewers asked additional probing questions to identify concerns or difficulties related to water use in specific contexts: at night, during monsoon season, while caring for dependents, and during pregnancy. Interviews lasted between 30 and 90 min, were digitally recorded, and took place in a private space identified by the participant, typically the participant’s home. After each day of data collection,

interviewers reviewed notes from each interview, summarized them, and discussed each interview and key themes that arose with the broader research team. Data collection continued until saturation of issues was reached within each of the four life stages (Hennink et al., 2017; Hennink and Kaiser, 2021).

Data comprised 69 interview transcripts that were generated by simultaneously translating and transcribing recorded interviews from Oriya into English. To check the accuracy of the translation and transcription, 10% (i.e., 6 min of a 60-min interview) of each interview was independently transcribed in Oriya by a team member who had not conducted any interviews, and a separate team member then translated Oriya transcription into English. This was then compared with the simultaneous transcription and translation of the same segments of data to check accuracy.

2.5. Data management and analysis

All data were managed using MAXQDA 2018 (VERBI Software, 2018). We used a grounded theory approach to analyze the data which involved the following steps. First, a preliminary codebook was created a priori, from topics and questions in the interview guide. Data were then read and memos were written to capture specific concerns, behaviors, and issues raised by participants themselves. Several close readings of the data generated further inductive codes that were added to the codebook. All relevant data were then coded which allowed the analysis to focus on specific topics one at a time. Each code was reviewed in detail, and categories were developed to capture water needs, preferences, and challenges to accessing water sources. These categories of needs were then compared across life stages to identify patterns and linkages. Links between categories were explored and conceptualized into an explanatory framework (Figure 1) to show how women select water sources. All components of the framework were validated by continually returning to the data to confirm linkages, by considering negative cases and their contexts, and through discussion with analysts, wherein three researchers reviewed data to confirm results were evidence-based vs. individual interpretations.

2.6. Ethics and informed consent

The Emory University Institutional Review Board in Atlanta, Georgia, USA (IRB00072840) and the KIIT University Ethics Review Committee in Bhubaneswar, India (KIMS/KIIT/IEC/795/2014) approved study protocols. Women provided oral consent to participate in interviews and for the recording.

3. Results

Participants reported multiple reasons for domestic water use, including drinking, cooking, bathing, washing utensils, washing clothes, washing menstrual cloths, and anal cleansing. Participants acquire water from a variety of sources, including private and public wells, private and public ponds, rivers, and from water sellers. Women reported a myriad of influences that affect their selection of water sources beyond the specific use of water, including their personal characteristics, cyclical (e.g., day/night) or seasonal

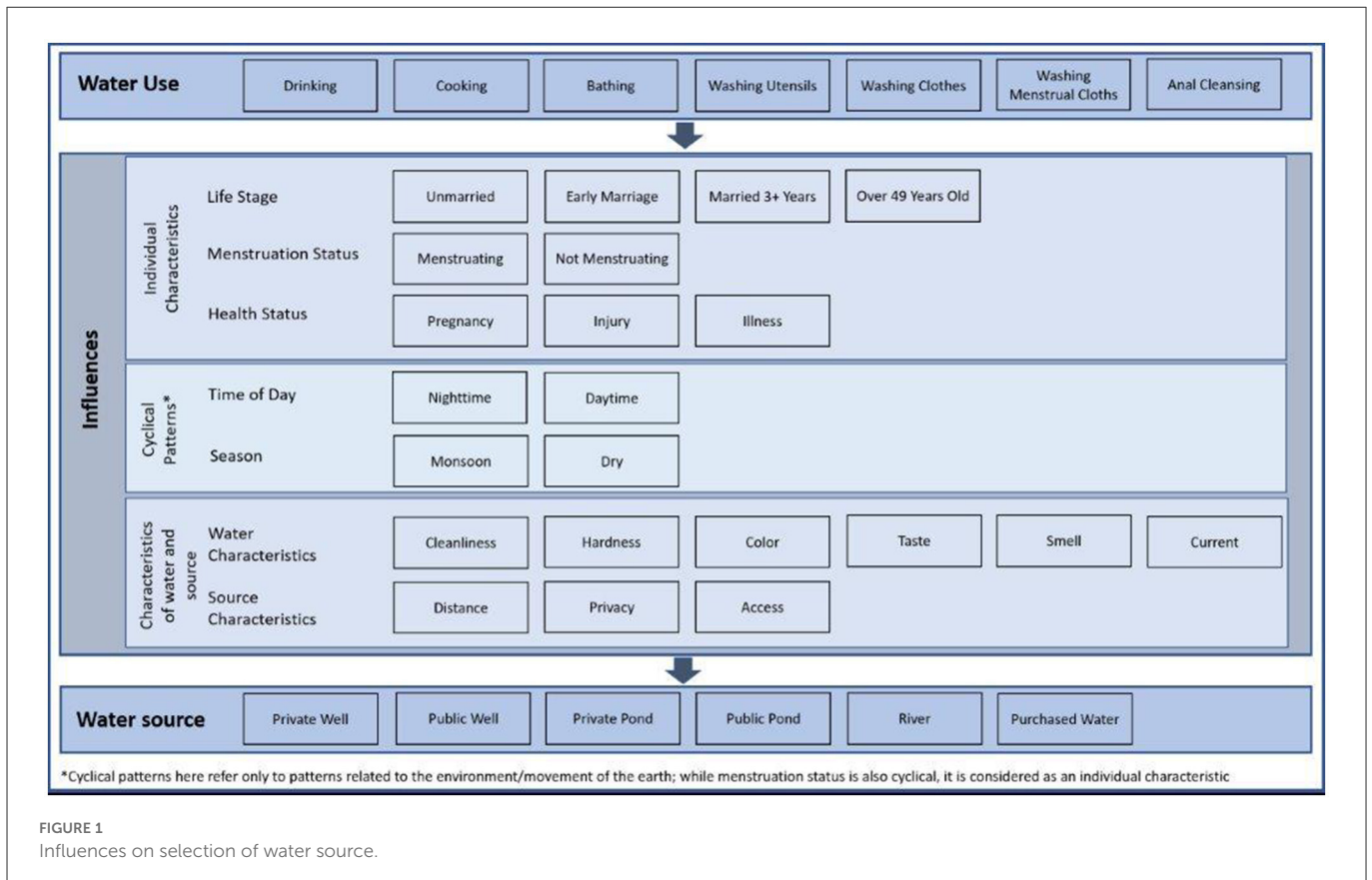


FIGURE 1 Influences on selection of water source.

influences and characteristics of the water and the source. Influences on water source selection also change over time and require concurrent consideration of multiple influences, creating a complex web of intermingling and compounding influences on decision-making regarding whether water at a specific source is acceptable for a specific need at a particular time. The influences on water source selection are summarized in Figure 1 and described in greater detail in the sections that follow.

3.1. Individual influences

Women reported that their selection of water sources, both for transporting home and for on-site use such as bathing or washing clothes at the water point, is influenced by their personal circumstances, such as life stage, menstruation, and health status.

3.1.1. Life stage

Unmarried women living in their parents' home (UMW) described water collection as their primary household chore. Several unmarried women claimed that water collection is their only responsibility apart from schoolwork, and they can usually complete this task without difficulty. These women reported fewer constraints on their freedom of movement before marriage than immediately after marriage. As UMW in this study reported fewer household responsibilities that require water, such as cooking, cleaning, or laundry, they have fewer water needs. However, UMW have to be mindful of their reputation in the community to secure husbands; if they are seen talking to boys during water collection, this may

negatively affect their reputation and marriageability. UMW reported more concerns over safety, such as fear of robbery or assault, when walking to water sources compared to older, married women. This perceived risk serves as a barrier to water collection, especially at night or from distant sources, affecting their decisions on where to get water.

Due to cultural tradition, recently married women (RMW) typically move into the home of their husband's family where they are expected to stay indoors and not be seen, meaning they rely on others in the household to access water for them. Even women in families with private water sources, for example, a well outside the house but within their household compound, reported needing other women in the family to fetch water for them. If the primary water collector, such as the mother-in-law or sister-in-law, is not at home, women reported having no water or insufficient water when needed. RMW who do fetch water themselves often have dependents, like small children or elderly in-laws to care for, and described either having to rush to fetch water or having to find someone in the family willing to provide dependent-care. Social support within the household, whether for water provision or dependent-care, is therefore necessary for RMW to meet their water needs.

RMW expressed differing levels of satisfaction regarding their reliance on others to meet their water needs. Some RMW are content to depend on their mothers- and sisters-in-law to fetch water as they feel shy in public. Others reported frustration that they must depend on others to meet their water needs. Women without sisters-in-law or a reliable social network of women in the household shared concerns about not having sufficient water to drink or bathe. One RMW who is not a full-time resident of the study area refused to adhere to constraints on movement that prevent water collection, causing

friction with her husband's family. She and her husband moved to a city where she has more freedom of movement, and her parents-in-law in the area disapprove when she refuses to remain at the family home when visiting them.

Women who have been married for several years (MW) and are in their thirties or forties, are often the primary water collectors for their household as they have the fewest constraints on their freedom of movement. They have fewer cultural norms restricting their movement outside the house than RMW, and they reported fewer physical infirmities preventing them from accessing water sources than OW. As more senior members of the family, especially if they have borne children, they have fewer restrictions on their mobility and are likely to be assigned the task of water collection by their mothers-in-law who may not have the health or the desire to fetch water themselves. This life stage group reports the highest burden of work, as they do not have sufficient authority in the family to delegate chores to other women.

Older women (OW) often have more physical limitations that affect water collection. They reported tiring easily, difficulty pumping water, and having sore hands, preventing them from carrying heavy loads of water. However, OW have more power in the household than women in other life stages, and they use that authority to delegate water collection to their daughters and daughters-in-law living in the house, particularly if they are unable to fetch water without help. Women without daughters-in-law reported a concern that their sons would not find wives to help them with household chores like water collection. Some OW who are physically able to carry water serve as the primary water collector, as they have more freedom of movement to leave the household and are less likely to report fear of assault or robbery during water collection.

3.1.2. Menstruation status

Women's menstrual status affects the amount of water needed to meet their needs. During menstruation women need more water to wash their bodies, and soiled menstrual cloths, clothes, and bedsheets. Washing sheets requires carrying so much water that women reported sleeping out of their beds when expecting to begin menstruation to avoid the additional work of washing soiled sheets.

Cultural norms around menstruation, such as the perception that menstruation is polluting, limit women's access to water, which may require them to seek help from others to meet their needs. When menstruating, women are not permitted to go inside temples, participate in festivals, or worship at their household shrines. In one village, the water source is located inside the temple, which prevents menstruating women from accessing the water. Women therefore have to rely on others who are not menstruating to fetch water from that source. Even women with private water sources in accessible locations face restrictions during menstruation and require help. Cultural norms require women to have a ritual bath as soon as menstruation begins. Prior to the bath, women have prohibitions on what they may touch, including food, beds, and household shrines. Some women discussed how they are unable to touch their household tube well until they have had their ritual bath. Women rely on support from female family members to collect water for the ritual bath. Unmarried women rely on their mother, sisters, or sisters-in-law to accompany them to the tube well to dispense water for the ritual bath and to carry and hold their clean clothes while they bathe; while married women rely on their mothers- or sisters-in-law. This dependence on family support begins at menarche and

continues through to menopause with no change due to age, marital, or motherhood status. Women described visiting some water sources without support during menstruation, such as ponds or rivers, demonstrating that some water sources are considered acceptable for their use during menstruation.

In addition to an increased need for social support, menstruation also requires the need for privacy when accessing water as women are embarrassed to have others witness them washing their menstrual cloths or bathing. Women who travel to rivers and ponds for cleaning cloths need to wait for men to leave those areas before they will wash bloodied materials. Even women with tube wells within their family compound reported additional privacy needs and embarrassment if seen. One participant reported that her father-in-law passed all of his time in the courtyard where the tube well was located, which presents challenges when she needs to take her ritual baths. She feels embarrassed when her father-in-law asks why she is bathing at an odd time and lies, saying she stepped in dog excrement for example, to avoid disclosing her menstrual status.

3.1.3. Health status

Changes in health status as women age or transition through different life stages can temporarily or permanently affect a woman's ability to fetch water. Pregnant women reported greater difficulties carrying water long distances. Women reported that water collection can exacerbate their menstrual symptoms, like stomach ache or weakness, particularly if they have to walk long distances in hot weather. Women with injuries and women with chronic or permanent conditions such as arthritis, incontinence, or physical limitations related to age also struggle to carry water or use the mechanical handpumps. These physical ailments or health conditions, whether temporary, chronic, or permanent, limit the water sources they can access, how often they can make the journey, how far they can go to fetch water, and how much water they can carry.

3.2. Cyclical patterns

Cyclical patterns also influence water source selection, including changes in time of day and season that may render certain water sources inaccessible or unusable for certain times of the day or year.

3.2.1. Time of day

The majority of participants indicated that water collection times are limited to daylight hours. Women do most of the domestic tasks requiring water during the day and are able to store water during daylight hours to accommodate nighttime drinking water needs, thus reducing the need for nighttime water collection. Because women avoid the task of collecting water at night, most did not identify safety issues related to nighttime water collection. The exceptional cases who did report collecting water at night largely did so due to unplanned events regarding water, and reported fearing snakes, dogs, vehicles, and people.

The most frequently reported unplanned event requiring water at night was the unexpected onset of menses. The onset of menstruation requires water for ritual bathing, which is already a struggle for many women during the day and is exacerbated at night. Social support

for getting water can be harder to obtain at night, when the family is asleep, and can vary by life stage. Young women living in their parents' home are more willing to wake their mothers and sisters for help than women newly living in their husband's home, who are hesitant to wake mothers- or sisters-in-law.

3.2.2. Season

Women reported that the water quantity, accessibility, and quality at a source change seasonally, impacting which sources they use. In the dry season ponds, rivers, wells, and boreholes produce less water. Reduced quantity of water and decreased water currents in river mean that women need to visit multiple locations to gather sufficient water, which can make water collection take longer. Participants described even greater difficulty for water uses that demand larger quantities of water, like bathing. Women who usually bathe in ponds or rivers could find water sources dried up or too muddy for use.

The rainy season similarly can affect the accessibility and quality of water at different sources. Accessing water sources becomes more difficult in the rainy season. Women are unable to carry water while holding an umbrella, so they reported getting wet or waiting until the rains stopped. Fetching water in inclement weather presents additional safety concerns, such as slipping and falling because the paths were slippery from rain and "siuli" (an algae-like growth). Mosquitoes that breed in standing water or leeches that live in muddy areas may bite women as they collect water. One participant reported compounding physical and social barriers to water access noting that the rain creates a swamp that prevents her from taking her usual path, and her uncle will not allow her to detour across his land, which would be the quickest and safest alternate route.

Women reported that heavy rains can change the water quality. Rains increase the insect population, which can get into the well water, resulting in some participants having to change water sources. Other participants reported greater satisfaction with water during the monsoon season. The water level in ponds, rivers, and wells is higher, which makes it easier to use or collect a sufficient quantity of water for bathing, washing, and rainwater harvesting for water collection, storage, and use. One participant reported additional water needs during monsoon season, as her duties caring for livestock require her to bathe more frequently, but those needs are mitigated by the more easily available and plentiful water supply.

3.3. Characteristics of water and source

Women's choice and preferences of water sources are also influenced by the characteristics of both the water itself and the source it comes from. The characteristics of the water from different sources affect women's perception of water quality for different household needs, which in turn drives their choice of water source. Participants require the highest water quality for drinking and cooking, meaning water that has no color or smell and is not perceived as dirty, chemically contaminated, or hard, but they still have to make choices on which quality standards they most prioritize. Water that is iron-rich or saline does not taste good for drinking, and it can affect the taste and smell of rice boiled in the water, leading participants to use alternate sources. One participant reported feeling forced to use pond water to cook even though she perceived the water as dirty, because

she said the tube well produced hard water that turns pakhala, a traditional rice and water dish, to "live saliva." A participant from the same village likes the water in her tube well for drinking, and described the taste as "sweet" but still uses the pond water to cook, despite having to filter and boil it, because she claims the tube well water spoils the food and makes it smell. In another village, a participant used a well at a nearby school until the water became yellow and saline. At this point, she began using a tube well from another village that she has to walk to, even though she suffers verbal abuse from the local villagers who do not want women from outside the area using their water point.

Different water quality concerns were reported for water used for washing clothes or bathing. Several participants prefer to draw water from sources other than conveniently located tube wells because their tube wells produce water that is iron-rich and red in color, which then stains clothing if used for washing. Participants reported that ponds contain large amounts of trash, and rivers may have cows being bathed or dead animals and feces in the water, so disgust at the water quality and the smell prevents them from bathing there if there are other options available. If the water from sources such as rivers is sufficiently clean, participants prefer these sources for bathing or washing clothing, as the flow or current of the water facilitates these activities.

In addition to the characteristics of the water, the characteristics of the water source itself can influence which water source to use. Distance, access, and privacy are all considerations for water source selection, depending on the specific water use. If large quantities of water need to be collected and carried, some participants reported going to sources within a shorter distance from their home, as walking long distances with large quantities of water is physically tiring and time-consuming. However, distance may not be as prohibitive a factor if smaller quantities of water are being collected for drinking from a source perceived to be high-quality.

Privacy is an important influence when finding a source for bathing or tending to menstrual needs so participants can maintain dignity. Participants do not want to be seen by men when bathing, so they may choose to use ponds in their back yards, even if those ponds are dirty. Several women discussed the importance of not being seen when washing cloths used for menstruation. This can result in using dirty ponds to clean menstrual cloths, and several women complained of infections that they believe happen as a result. Some participants reported waiting at rivers until others are done using them in order to have the privacy necessary for bathing or washing menstrual cloths.

Some water sources may be selected or avoided due to the ability to access them comfortably or easily. Pathways to the water source may shift as a result of floods, or become unusable at night due to safety concerns. Participants also reported experiencing social barriers to accessing some water sources. Participants can be harassed or blocked from using certain sources by other users, as experienced by one woman who tried to use the water point of a neighboring village. Another young girl reported that despite the presence of a private tube well near her house, she was not comfortable using it because boys would congregate there, drinking and spitting.

4. Discussion

Women in rural Odisha reported a variety of household needs that require water and noted that decisions on source selection

are based on numerous influences including, but not limited to, the intended use of the water they are fetching. Other influences include individual characteristics that may affect their ability to access sources, such as physical limitations as noted by women who were elderly, physically disabled, or pregnant; or cultural norms, such as menstrual restrictions or constraints to movement among women who were newly married. This research is consistent with findings in a recent systematic review, which found that using multiple water sources is common, and water source selection is governed by water quality and a series of concurrent assessments of resource efficiency that consider cost, distance, and time, and shift between wet and dry season (Daly et al., 2021). Findings illuminate the importance of considering multiple water sources when designing water access systems and monitoring water access, as households may not have a clearly defined primary source of water, and source selection can vary throughout the year based on seasonality (Box 1).

Our findings are particularly important in the context of Jal Jeevan, the local government's expansion of piped drinking water schemes toward rural households in Odisha. We found multiple water source use to be common despite high coverage of tube wells at the household level. It will remain critical to assess multiple water source use as the piped water scheme goes into effect to understand if and how use of multiple sources has changed, including what influences women's decisions about water sources selected. These piped schemes may not achieve the expected uptake if they do not produce water perceived to be acceptable by women (Kulinkina et al., 2016). As the focus of the scheme is limited to drinking water, women may continue to collect water from multiple sources for other household uses, particularly if they are not consulted on placement of the tap. Past research in Puri district has shown that women have not been consulted on placement of latrines, resulting in latrines that were not used because they did not sufficiently meet women's needs (Routray et al., 2017). Restrictions that prevent women from touching water sources before they have had their ritual bath at menstrual onset will likely remain, meaning that new water sources may not alleviate the need to seek social support or alternative water sources. As demonstrated in these results, women are the primary decision-makers and collectors of water, so it is crucial for them to be consulted as this scheme moves forward. Further, the piped water scheme should be evaluated not only to assess if it provides clean water, but if gender-specific impacts—which are often ignored (Caruso and Sinharoy, 2019)—are realized, including improved safety, time savings, and reduced harm, injury, and labor (Box 1).

These findings are consistent with existing qualitative research that has demonstrated a variety of cultural influences on women's ability to use certain sources, particularly in multi-generational households. Daughters-in-law in rural Bangladesh have been found to collect water from arsenic-contaminated sources near houses, instead of traveling outside the house and therefore exposing the family to disgrace (Sultana, 2009). Older women may have fewer restrictions on their movement, but as senior women in the household, they are able to delegate chores such as water collection to daughters-in-law (Sultana, 2009). Similarly, our results show that recently married women who were not able to leave the house due to cultural traditions also had limited access to water sources, resulting in stress over their reliance on other family members to meet basic needs. Additional cultural constraints in this population, which are described more thoroughly by MacRae et al. (2019)

prevent menstruating women from accessing water as needed, despite increased water requirements during menstruation. This research demonstrates that not all women within a household have equal access to water, thus monitoring efforts that presume the presence of a household water source is sufficient to result in equitable water access for *all household* members may be over-estimating access, even if the source is located on the household premises. Monitoring water access at the individual level for uses beyond drinking water alone could provide more accurate assessments of equity than current assessments at the household level, and would be consistent with a recent call for greater consideration of gender in WASH-related monitoring (Caruso et al., 2021) (Box 1).

This study supports the importance of user acceptability of water, finding that participants prioritize *perceived* quality of water, which includes odor, taste, and appearance (World Health Organization, 2022). The Joint Monitoring Programme for Water Supply, Sanitation, and Hygiene (JMP) collects and reports on water sources to track progress toward the SDG target of “universal and equitable access to safe and affordable drinking water for all” (UN General Assembly, 2015). The gold standard, “safely managed drinking water sources,” or improved sources that are “accessible on premises, available when needed, and free from fecal and priority chemical contamination” (JMP), not only ignores other household water priorities, but only judges water quality according to microbiological, chemical, and radiological standards which ignore users' priorities for acceptability (World Health Organization, 2022). In Ghana, qualitative research found that people avoided piped water systems that produced salty water not only because of taste, but also because soap wouldn't lather when doing laundry (Kulinkina et al., 2016). In several communities in rural Vanuatu, households chose rainwater over groundwater for drinking and cooking, despite microbiological testing showing that rainwater had higher levels of *Escherichia coli* contamination (Foster and Willetts, 2018). This research supports those results, finding that iron-rich or saline water is not perceived as acceptable for drinking or cooking, leading participants to avoid using water from improved sources nearby. The JMP core questions for household surveys assume one primary drinking water source; monitoring efforts should, whenever possible, use the expanded questions in order to capture information on multiple water sources for drinking.

This research further demonstrates the importance of seasonality in water source selection, and understanding multiple water source use may become increasingly important as the climate continues to change and seasons grow more unpredictable or extreme. Water sources may change between wet and dry season, as a result of changes in quality and availability in sufficient quantities (Elliott et al., 2017; Daly et al., 2021). Communities that rely on rainwater during the wet season may require different or supplementary sources in the dry season and may resort to purchasing water for vendors, spending long wait times at shared water points, and using less water (Kulinkina et al., 2016; Daly et al., 2021). Rainy seasons have their own risks, as heavy rains can contribute to contamination of surface waters and increases in water-borne diseases (Ahmed et al., 2020). In their exploration of multiple water source use in developing countries, Elliott et al. (2019) suggest that the use of multiple water sources diversifies risk and builds resilience, which can therefore help lead to water security in an unpredictable climate. Given the shifts in water source use based on seasons, surveys should consider the

BOX 1 Implications for policy and practice.

- **Monitor the use of multiple water sources for a more comprehensive understanding of needs and practices.** Current national and global monitoring efforts only query the “primary” or “main” water source used for drinking, which dismisses both the possibility that multiple water sources may be used and that water needs extend beyond drinking. Further, those with improved water source access may still use other sources for drinking and other needs. The source used as the primary or main source for drinking also may change depending on a variety of influences, including seasonality, perceived water quality, and specific need. The narrow approach of monitoring just the primary drinking water source type may over-estimate access and use of optimal sources. Thus, monitoring efforts should assess the use of multiple water sources for both drinking water and other uses to ensure all practices are assessed more accurately.
- **Monitor individual-level water access and use, not just access and use at the household level.** Current monitoring efforts focus on assessing water access at the household-level, which assumes water is equally accessible to all household members. However, household-level data collection is gender-blind, obscures differential access to water within a household, including women and girls, individuals with physical limitations, and other groups who may experience physical barriers or socially-mandated restrictions to their access, and ignores those who are unhoused. Current progress toward the SDG 6.1 goal of safe and accessible water for *all* may be over-estimated based on these assumptions. Individual-level monitoring data on water access, use, and experiences could illuminate differences that are currently hidden.
- **Ensure equitable access to water sources.** Those involved in the delivery of water systems (e.g., piping) or other forms of water infrastructure (e.g., community bore-holes) should ensure equitable access to women, girls, and vulnerable populations. Water delivery efforts should not contribute to inequity by not providing services to all or by placing infrastructure in areas that may be inaccessible to some, whether due to physical or social barriers.
- **Design interventions for household water for domestic uses beyond drinking and cooking.** While improving the quality of water for consumption is important for reducing risk of pathogen exposure, initiatives that seek to improve water access should consider water needed for bathing, washing clothes, and other uses. Focusing on improving drinking and cooking water alone misses the opportunity to positively impact the lives of women who largely are responsible for all water needs. Improving water access for all needs could also result in reducing time burden, physical labor, and safety risks of water collection and water-related tasks that women shoulder.

season of data collection. Further, future research should also assess if and how climate change impacts water sources used and why, with particular attention to women’s decision making and experiences given the likelihood that they will be particularly impacted (Sinhroy and Caruso, 2019).

4.1. Strengths and limitations

A major strength of this study is that participants were asked an open-ended question about concerns related to water use, which enabled them to share behaviors such as multiple uses of water, including drinking, cooking, bathing, anal cleansing, and washing utensils, clothes, and menstrual cloths. Asking about the full range of water use beyond drinking water enables a more complete and nuanced description about water needs, experiences, and challenges than studies that are limited to drinking water or household-level assessments of access alone. Despite evidence of the importance

of water for productive uses (Hall et al., 2014), the open-ended questioning did not prompt participants in this context to indicate concerns about water for productive purposes (e.g., gardening, caring for livestock, or income-generating activities). Probes could be added to future work about water uses and water-related concerns related to productive use as confirmation. Additionally, because this research focuses exclusively on women, men’s decision-making regarding water selection and use and gendered household dynamics were not explored. Future research can investigate perceptions from men and women.

This study engaged rural women in Odisha and its findings are limited to that population. While the study population included women from various castes and tribes, there were no questions asked about water source decision-making related to caste. Other studies have found that caste may limit women’s ability to access certain sources for water collection (Singh, 2006; Narain, 2014; Leder et al., 2017) or bathing (Sahoo et al., 2015), and so additional study is warranted. However, because of purposive sampling among women of different ages and marital statuses, from different villages, and with different water and latrine access, there is diversity in experience and variability in the data. Girls under age 18 were excluded from data collection, so their voices are only represented through adult participants’ sharing of their past experiences or the experiences of other, younger women they know. The deliberate inclusion of women over 49 years of age is an important contribution. Research tends to focus on girls and women of reproductive age, but increases in age are associated with higher rates of disability, which result in poorer WASH access (Mactaggart et al., 2018).

5. Conclusion

A growing body of work has explored the prevalence and importance of understanding multiple water source use. The interweaving influences on water source selection are important to understand from a monitoring perspective, where calls have been made for a greater consideration of gender in data collection, and also from the perspective of those designing and implementing public health interventions. Consideration only of water quality and quantity and location of water source may result in underperforming interventions. Extending water sources to homes or communities should take into consideration cultural norms that may limit access to water and community perspectives on what makes a water source acceptable.

Data availability statement

The datasets presented in this article are not readily available because: ethical restrictions prevent these data from being publicly shared. Participants did not consent for their data to be shared with anyone outside the research team. While this analysis focuses on water, the full data include more sensitive information on menstruation, urination, and defecation practices, and how these practices result in shame and embarrassment to individuals and families. Participants were assured of their privacy and the confidentiality of the data. Requests to access the datasets should be directed to: bethany.caruso@emory.edu.

Ethics statement

The studies involving human participants were reviewed and approved by Emory University Institutional Review Board in Atlanta, Georgia, USA (IRB00072840) and the KIIT University Ethics Review Committee in Bhubaneswar, India (KIMS/KIIT/IEC/795/2014). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

MP conducted the formal analysis, contributed to interpretation of results, created the conceptual model, and wrote the original manuscript. MH contributed to the supervision of the analysis, interpretation and validation of the results, and review and revision of the conceptual model. MD and MR contributed to the investigation, data curation, and validation of the results. TC acquired funding and resources and administered and supervised the project. BC conceptualized the interview guide and methodology, contributed to the investigation, data curation, administration of the project, contributed to the supervision of the analysis, interpretation and validation of the results, and review and revision of the conceptual model. All authors reviewed, edited, and approved the final manuscript.

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