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PERSPECTIVE OPEN

Addressing how multiple household water sources and uses build water resilience and support sustainable development

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The routine use of multiple water sources to meet household water needs is widely practiced and has been reported in many developing countries. However, it is typically neglected by implementers, development organizations, and researchers who tend to focus exclusively on the "main source of drinking water." In this Perspective, we explain the nature and scope of multiple water source use (MWSU) at the household level in developing countries. We also describe the implications of MWSU for human health and water resilience, and identify key knowledge gaps, risks, and opportunities associated with MWSU. Finally, we argue that understanding MWSU is feasible for researchers and implementers and is essential for properly designing research studies and water supply projects.

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INTRODUCTION

In high-income countries, it is typical for all or nearly all household water needs to be supplied by a single source: high-quality municipal piped water, occasionally supplemented with bottled water. In contrast, in low- and middle-income countries, households often use more than one source to meet their daily water needs, with water sources selected according to use and often changing across seasons.[1–3] For example, a family in rural Africa may collect a jerrycan of high-quality water from a distant borehole and use it only for drinking and/or cooking, but bathe and wash clothes with water from a nearby shallow well; or a household in an area with highly seasonal rainfall may use rainwater tanks for all household purposes during the rainy season but ration stored rainwater for only drinking during the dry season. This practice of using multiple sources of water, for different domestic purposes, has been reported in many countries across Asia, Africa, the Americas, and the Pacific but is broadly neglected by the global water sanitation and hygiene (WaSH) and development communities, as interventions, strategies, surveys, and data sets focus almost exclusively on a household's "main source of drinking water."

The objectives of this paper are to: (1) provide a brief overview of the evidence that the use of multiple household water sources is both widespread and fundamental to household activities across developing countries; (2) illustrate why and how conventional approaches focusing on the "main source of drinking water" are inadequate; (3) make the case that use of multiple sources must be understood by the global WaSH community to design appropriate and effective interventions; (4) describe the opportunities and risks associated with multiple source use; and (5) make an appeal for the global WaSH community to integrate multiple source use into monitoring, research, and implementation.

CONVENTIONAL APPROACH: FOCUS ON "MAIN SOURCE OF DRINKING WATER"

When the Millennium Development Goals were established in the early-2000s, the need for a consistent set of questions about household water and sanitation was recognized by the WaSH and development community. A list of questions, for use in censuses and other household data collection instruments, was consolidated by WHO and UNICEF.[4,5] For household water, the focus was on the "main source of drinking water" for all members of the household with a single question:

"What is the main source of drinking water for members of your household?"

The core questions did notionally include a second question relating to water source used for "cooking and hand washing." However, survey skip patterns in the most widely used surveys, like Demographic and Health Surveys (DHS) and Multiple Indicator Cluster Surveys (MICS), dictate that this second question is only triggered when a household reports packaged water (e.g., bottled water) as the main drinking source.

A narrow emphasis on a primary drinking water source was embedded in a public health rationale, alongside an imperative for a simple and consistent indicator against which drinking water-related development can be measured. Additionally, the inclusion and retention of questions in censuses and other nationally representative surveys is a competitive process; limiting the complexity and number of questions used in DHS and MICS increases the likelihood that the core questions will be included, and thereby increasing the body of internationally comparable data. The UNICEF and WHO Joint Monitoring Programme (JMP) aggregates these data to generate national and global estimates. The JMP database includes water and sanitation survey data from nearly 500 nationally representative surveys supported by UNICEF and WHO and over 1200 nationally representative surveys

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supported by other entities.[4,6] The core questions on drinking water appear to have been broadly adopted and integrated globally, with future implementation indicated by their recent enshrinement in Sustainable Development Goal 6.1 (https://www.un.org/sustainabledevelopment/water-and-sanitation/).

This focus on the primary drinking water source is certainly defensible for generating a consolidated and comparable global approach to nationally representative surveys. However, what may be ideal for survey organizations and aggregated global datasets is not necessarily an adequate representation of all communities impacted by WaSH practitioners and researchers, particularly with respect to focused studies or implementation of infrastructure and services in specific settings. In the following sections, we provide evidence that routine use of multiple water sources is widespread and essential for households around the world, and that understanding multiple water sources is essential to research and practice and, ultimately, the water-focused outcomes of people in the developing world.

USE OF MULTIPLE HOUSEHOLD WATER SOURCES: WIDESPREAD, DIVERSE AND ESSENTIAL

Although long-acknowledged among field researchers and practitioners, multiple water source use (MWSU) received little attention and almost no detailed study, outside of efforts by economists to model household behavior when multiple water options were available.[7,8] Indeed, many researchers have overlooked the complexity of multiple water source use either inadvertently or by design. This may stem from the difficulty of developing appropriate survey instruments that accommodate untold combinations of water sources used for different reasons and across seasons. For example, in *Drawers of Water II*, Thompson and colleagues acknowledged that households accessed different water sources according to use and season before reiterating their insistence that survey respondents designate a primary source and answer questions only on that source.[9]

A survey instrument developed by Whittington[10] enabled the investigation of multiple water sources. However, few researchers or implementers adopted it, as the complexity and detailed skip patterns made enumerator training and data collection both time-consuming and error-prone. These challenges have been largely overcome through the development of computer-assisted personal interviewing (CAPI) approaches, as discussed by MacDonald et al.[11] Prior to 2010, only a few articles reporting in detail or quantifying the use of multiple water sources had been published[12–14] but in recent years there has been a marked increase in research interest.[1,3,15–19]

The routine use of multiple household water sources is practiced across settings that vary in precipitation patterns, water resources, piped water availability, etc. For example, it has been reported in many countries across Southeast Asia,[17,20–22] Sub-Saharan Africa,[2,3,12–16,22–24] North Africa,[25] Western Asia,[26] East Asia,[27] South Asia,[8,28] Oceania[1,11,19], and Latin America.[18,29] Use of multiple sources in wealthy countries typically involves tap water and bottled water for consumption and other indoor uses, with limited use of harvested rainwater, gray water or shallow well water for aquifer recharge, gardening, and irrigation.[30,31]

RELEVANCE OF MWSU TO GLOBAL DEVELOPMENT, HEALTH AND CLIMATE RESILIENCE

A narrow emphasis on the primary drinking water source captures some but not all aspects of household water and health, including handwashing. Neglecting other household water sources and their uses also fails to address the main ways in which household water affects development, health, and climate resilience.

With the widespread practice of MWSU, the existing monitoring frameworks may fail to identify risks associated with water sources used for handwashing if they differ from drinking sources. However, the proximity and consistency of a supply used for handwashing has a strong impact on handwashing frequency and thus can have a major health impact.[1,15,25,32–35] Additionally, with respect to economic development, it warrants mentioning that having water for productive purposes plays an important role in the ability of households to lift themselves out of poverty.[36]

MWSU appears to have strong potential to enhance household resilience to climate variability and change.[37] The ability of households to access water from sources that are differentially vulnerable to climate-related hazards can reduce the likelihood that all water sources become unusable during a single event (e.g., drought, flooding). In this way, MWSU can be considered analogous to approaches used by municipal water utilities in wealthy countries, where the sustainability of supply is enhanced through the use of multiple reservoirs or interconnections with other municipal piped systems. In some communities, the most common household use patterns seem to have been designed to ensure that water of appropriate quality is available for each use throughout the year (e.g., rationing stored rainwater for drinking during the dry season).[1]

OPPORTUNITIES AND RISKS ASSOCIATED WITH MWSU

The global prioritization of primary drinking water source informs (and arguably limits the scope of) innumerable data collection efforts. Therefore, there is still much we need to learn about how households pick and choose their water sources for various uses. Evidence from the Pacific suggests that many households tend to use the same source for drinking and cooking, and other sources for non-consumptive uses,[1] although further investigation is required to determine whether this dynamic holds in other settings. Seasonality heavily influences the choice of water source, as rainfall affects the relative availability, price and aesthetic attributes of different water sources.[1,2,15,16,38] This highlights another potential weakness of conventional monitoring efforts: the prospect of a systematic seasonal bias impacting the way national and global statistics are derived, through household surveys that mostly take place in the dry season (Table 1).[39]

MWSU presents both an opportunity and a risk for advancing the health and welfare of low-income households. For example, switching between drinking sources may constitute a 'high-risk' practice that heightens the chance of exposure to water-borne pathogens.[16] There are also reports of vector-borne diseases increasing when open or standing water sources are introduced close to villages[40] and this must be considered when implementing sources that are dependent on storage (e.g., rainwater collection). While there is still a paucity of evidence on this in a multiple water source context, analogous studies indicate even momentary lapses in water quality could have major health ramifications;[41–43] therefore, provision of low quality, high volume sources must be considered in the context of possible consumption. The flipside is that multiple water source use can be leveraged to improve water security for the poor. A portfolio of different water sources is often purposively adopted by households as a way to avoid overreliance and depletion of a single highly valued source, and therefore bolster resilience. Diversifying risk in this way may become even more important as climate change increases the variability and unpredictability of rainfall regimes. Most water is used for non-drinking purposes, so one must be wary to assume low-income households want to pay for water of high microbiological quality if it is only to be used for washing, bathing, or productive purposes. In that sense, the opportunity may not be dissimilar to dual system approaches being explored by utilities in high-income countries.

In order to adequately mitigate the risks and exploit the opportunities associated with MWSU, a more sophisticated understanding of how, where and why people choose their water

Table 1. Representative use of household water sources by type of use and season in four settings

		Wet season				Change from wet to dry season			
		Drink	Cook	Handwashing	Bathe	Drink	Cook	Handwashing	Bathe
(a)									
Typical city in high income country[30]	Piped water	87%	100%	100%	100%	—	—	—	—
	Bottled water	45%	—	—	—	—	—	—	—
Rural communities in Mekong Delta, Vietnam[17]	Rainwater (private)	85%	78%	64%	66%	−1%	−14%	−55%	−53%
	Private well	9%	17%	33%	30%	+2%	+1%	+6%	+7%
	Vendor/Tanker	0%	1%	1%	1%	+4%	+8%	+14%	+13%
	River/Stream/Pond	1%	3%	15%	13%	+2%	+3%	+9%	+9%
	Piped water	1%	3%	7%	6%	+1%	+1%	+5%	+5%
	Bottled water	10%	1%	—	—	+3%	—	—	—
Rural communities in Solomon Islands[1]	Rainwater (private)	22%	29%	39%	37%	−21%	−26%	−35%	−34%
	Rainwater (shared)	41%	39%	24%	14%	−30%	−26%	−20%	−13%
	Private well	5%	12%	16%	16%	+7%	—	−1%	−1%
	Public standpipe	34%	37%	38%	33%	+13%	+8%	−6%	−9%
	Natural spring	17%	18%	14%	11%	+9%	+8%	+2%	+2%
	River/Stream/Pond	7%	11%	58%	54%	+3%	+10%	+30%	+34%
	Bottled water	6%	6%	—	—	+1%	+1%	—	—
(b)		Drinking/ Cooking		Washing/Bathing		Drinking/ Cooking		Washing/Bathing	
Urban Lagos, Nigeria[12]	Rain	18%		25%		−18%		−25%	
	Ordinary well	20%		35%		−9%		−26%	
	Borehole	68%		37%		−2%		+18%	
	Public tap	18%		35%		+9%		+5%	
	Water hawker	38%		18%		−8%		+8%	
	Tap water	68%		50%		—		+20%	

Wet season values expressed as baseline on left, with change from wet to dry season on right. (a) Self-reported use in three settings. (b) Self-reported sum of Primary and Secondary water source use by season for Lagos. Percentages can exceed 100% if households report use of more than one source for a given purpose in a given season. Prepared based on the information obtained from refs. [1,12,17,30]

sources is needed. In addition, greater understanding of the water cycle and the pools and fluxes of available sources is needed in any given location, in order to map availability, accessibility, water quality, and community behaviors in a systematic way.[44] Despite the growing evidence of widespread MWSU in developing countries, there is likely to be substantial diversity in the way MWSU plays out across regions and between urban and rural areas (Table 1).

FILLING KNOWLEDGE GAPS FOR IMPLEMENTATION, RESEARCH AND POLICY

Addressing knowledge gaps around MWSU is critical for interpreting existing data, designing studies and implementing all manner of water supply and wastewater interventions. Critically, MWSU appears to have evolved independently in settings around the world in response to pressures and the values associated with local water resources. For example, similar traditional practices of rainwater collection and storage in remote communities with heavily seasonal rainfall with rationing during the dry season have been observed on distant Pacific Islands and in rural Vietnam.[1,17,19] It is unclear whether MWSU can be "implemented" in locations where it has not evolved indigenously and there are possible risks of providing new sources, as noted in the section above.

The most prominent approach for addressing water safety is the water safety plan (WSP) framework developed by the World Health Organization.[45] While WSPs have been successful in many settings around the world, it is unclear how appropriate they are for settings in which drinking water supply is dominated by dispersed household supplies (e.g., rainwater or private wells) or for evaluating health risks related to hygiene behaviors in the context of MWSU. More recent WSP reports and templates for small communities mention "alternative water supplies" and for these ask about "purpose of use"[46] but evaluation of those sources appears to be limited to their potential use for drinking. Additionally, WSPs do not appear to address the substantial health risks that can arise seasonally when water quantity is insufficient for handwashing and other hygiene.[15] More comprehensive Integration of MWSU into WSPs or alternative water safety frameworks should be explored.

At present, it is difficult to compare studies of MWSU, as there is a noted lack of precision and consistency in language between studies. For example, it is often unclear whether studies report "access to" a water source or actual "use of" that source. Additionally, there remains terminology challenges, such as "multiple sources" vs. "multiple source types" (e.g., all public wells could be counted as one source type). Research into water source choices comes with an inherent complexity, but with the emergence of electronic platforms for data collection—including automated logic—the task has become more feasible than it once was.[11] In addition to well-designed primary data collection efforts, we advocate for the analysis of those existing data sources that go beyond a"primary drinking water source." Examples include nationally representative surveys (e.g., Cambodia DHS) and national censuses (e.g., Vanuatu, Solomon Islands, Malawi, Myanmar).

In summary, MWSU represents a widespread yet under-reported practice in many households. As evidence emerges of this practice across a growing range of contexts, the time is right for researchers and implementers to measure, understand and incorporate this behavior in a way which will support the development and climate resilience in communities. Further research is needed to develop a more nuanced understanding of the conditions under which MWSU is beneficial or potentially harmful. The rise of digital data collection platforms and the sharing of survey resources to support data collection and analysis offers great potential. It is likely that a lack of understanding of MWSU has led to perverse outcomes of water interventions and precluded consideration of existing strategies that offer efficient and sustainable solutions.

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ADDITIONAL INFORMATION

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