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Research Paper

A longitudinal study of multiple water source use in Bekasi, Indonesia: implications for monitoring safely-managed services

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ABSTRACT

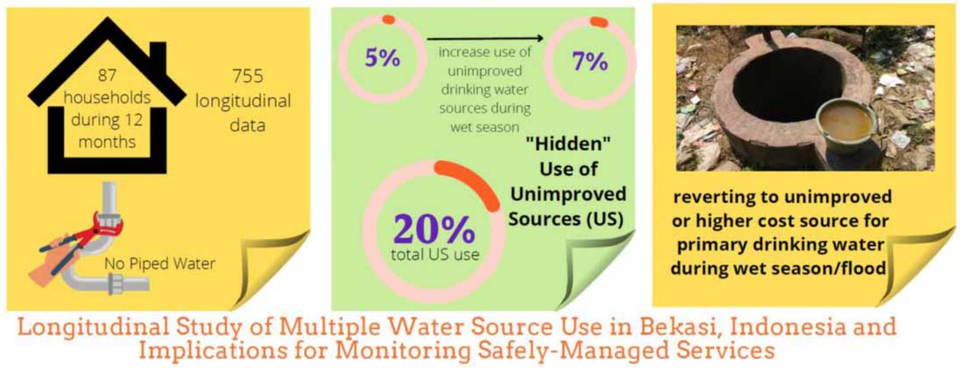
Limited piped water services in low- and middle-income countries (LMICs) are likely to increase the use of multiple water sources, impacting access to safely managed water. The aim of this study was to analyze monthly variations of households' water source preferences in three subdistricts in Bekasi, adjacent to the capital city of Indonesia, through a monthly telephone survey of 87 households during 12 months. Households with 1, 2, and 3–4 drinking water sources formed 70, 27, and 3% of the 755 total responses, respectively. Of the 53 households that completed at least 11 of the 12 monthly surveys, around 32% of households resorted to other water sources as a complement for drinking water and other domestic purposes. Households switched from borehole water to bottled water for their primary drinking water in the wet season but still used borehole water as their complementary source. Unimproved source use as primary drinking water also increased during the wet season from 6 to 8%. Monitoring and risk assessment of water sources need to consider the use of multiple water sources while balancing out the limited resources to protect the population, especially the vulnerable, from unacceptable health risks.

Key words: drinking water, groundwater, low-middle-income country, multiple water source use (MWSU), seasonality, temporal variation

HIGHLIGHTS

- At any given time, 30% of households had multiple drinking water sources.
- For all water use, multiple water sources increased to 74%.
- Borehole water use decreased by 6% during the wet season replaced by bottled water.
- Primary drinking water from an unimproved source at 2%, higher during the wet season.
- Use of unimproved sources as overall drinking water tripled, at 20%.

GRAPHICAL ABSTRACT



ABBREVIATIONS

BPS	*Badan Pusat Statistik* or national statistical agency
CWS	complementary water sources
DFAT	Department for Foreign Affairs and Trade
DHS	Demographic and Health Survey
DWPS	drinking water perceived as safe
JMP	Joint Monitoring Program
LMICs	low- and middle-income countries
MICS	multiple indicator cluster surveys
MWSU	multiple water source use
PCDW	primary and complementary drinking water
PCWS	primary and complementary water source
PDW	primary drinking water
PWS	primary water source
SDG	Sustainable Development Goal
SUSENAS	*Survey Sosial Ekonomi Nasional* or social economic national survey
SUSU	supplementary unimproved source use

INTRODUCTION

Safely managed drinking water is the highest service level on the Joint Monitoring Program (JMP) ladder for global monitoring of the Sustainable Development Goal (SDG). Safely managed drinking water sources should meet these three criteria: an improved source that is located on-premises, available when needed, and free of fecal and priority contamination (WHO 2017). In 2020, while 93% of the population in low- and middle-income countries (LMICs) used improved water, only 58% of the total population is reported using safely managed drinking water (WHO/UNICEF 2020). Additionally, only 46% of the population with improved sources reported using piped water (WHO/UNICEF 2020). Household with limited piped water service is likely to use multiple water source use (MWSU) as a strategy for securing their water needs (Neumann *et al.* 2013; Kulinkina *et al.* 2016a). For example, a household in Vietnam with no piped water network relies more than a household with a piped water network on bottled water in conjunction with other sources (Neumann *et al.* 2013). In Ghana, poor piped water quality is one of the reasons for households complementing their water source with complementary sources such as dug well and rainwater (Kulinkina *et al.* 2016a).

Current monitoring programs for safely managed drinking water are usually limited to capturing one main source of drinking water at a given time. Previous studies underlined how this type of monitoring masks the complex reality of households that use multiple water sources and may underreport the health risks associated with unsafe drinking water (Elliott *et al.* 2019). It is estimated that 42.3% of households across Asia and Africa use more than one source of water (Vedachalam *et al.* 2017).

On one hand, multiple water sources offer flexibility to households by allowing them to supplement or alternate water sources according to the level of service (Cassivi *et al.* 2021). However, each water source may carry different health risks. In certain circumstances, households supplement their improved water source with an unimproved one (Daly *et al.* 2021), coined as 'supplementary unimproved source use' (SUSU). Households may also voluntarily opt for improved sources that are not necessarily safe (Foster & Willetts 2018). Monitoring access to safely managed drinking water needs to consider a temporal variation of households' access to various water sources and their specific use.

In the last 10 years, only a few studies have been conducted in South-East Asia on multiple water sources such as water quality of multiple water sources in Kandal Province, Cambodia (Shaheed *et al.* 2014) and the influence of income on MWSU in Bandung, Indonesia (Nastiti *et al.* 2017). Shaheed *et al.* (2014) found the mixing of MWSU, including from improved and unimproved sources, might be associated with poor water quality. Nastiti *et al.* (2017) noted that MWSU was more common in higher-income households. Some studies on multiple water sources in South-East Asia focused on comparing secondary water sources with a specific main source, such as bottled water (Francisco 2014). They may not include a multitude of other water sources because they focus on a specific water source as the main topic. MWSU was not the focus of their discussion, even though MWSU was examined and captured by those studies.

The aim of this study was to capture and analyze monthly and seasonal variations of MWSU and to understand the overall preference of each household when choosing water sources for various activities throughout the year. This study was conducted in Indonesia, the most populous country in South-East Asia, where piped water is accessible to only 20% of the population (Bappenas 2021), and only half of those who have access to it use it for drinking purposes (BPS Kota Bekasi 2021). The study focused on urban areas, which have a higher population density. To the best of our knowledge, this study is the first that has focused on MWSU in South-East Asia and the first longitudinal multiple water source study that has surveyed households for 12 months.

METHODS

Study location

The participating households were situated in Bekasi City, Indonesia focusing on three districts in Bekasi City (2.54 million people; 12,085 people/km^2) namely Jatiluhur, Sumur Batu, and Jatirangga (Figure 1), chosen due to its high population density, low access to piped water, and widespread use of self-supply groundwater services. It is in the West Java Province and is directly adjacent to Jakarta, the capital of Indonesia. In 2020, more than 88% of the households depended on groundwater as their water source and most of these households were in the bottom 40% of expenditure (BPS Kota Bekasi 2021).

Data collection

From June 2020 to May 2021, a monthly survey was conducted through telephone interviews using digital platforms on the primary and complementary water source (PCWS) use for four activities (drinking water, coffee and tea, handwashing, and other domestic uses) and the perceived safety, taste, appearance, smell, and overall reliability of primary drinking water (PDW) source (Supplementary material, Appendix S1). This monthly survey is parallel to a larger field survey in the same area conducted from February 2020 (wet season) and October 2021 (dry season) involving approximately 300 households. Some data from this larger study were used to complete the monthly survey results, including the socio-economic profile and water quality. More details can be found in other published studies (i.e., Maysarah *et al.* 2020). Data on 23 indicators such as household asset ownership, dwelling material, cooking fuel, and household composition were also used from the larger aforementioned field study to calculate the wealth index and quintiles using the same method as in 2017 Indonesian Demographic and Health Survey (DHS). Rainfall data were obtained from annual reports of the national statistical agency (*Badan Pusat Statistik* or BPS) (Supplementary material, Appendix S2).

The 87 households selected for the monthly survey were a subsample of the field survey respondents. The inclusion criteria were as follows: (a) availability of telephone numbers, (b) willingness to participate in the monthly survey, and (c) point-of-use samples collected in the field survey. Within 12 months, 34 respondents withdrew their participation during the survey period or did not respond in some months. The study was approved by the Ethical Approval Committees of Universitas Indonesia (29/UN2.F10.D11/PPM.00.02/2020) and the University of Technology, Sydney. Informed consent was obtained from the households at the beginning of the survey (in February 2020) and before each monthly telephone call.

Data were analyzed from several angles categorized by participation duration of households and survey period. The first angle included 1-year data of the respondents who participated at least one time or which means all the data were obtained from 87 households. PDW, primary water sources (PWS), and complementary water sources (CWS) were analyzed separately and together, mentioned as a PCWS or primary and complementary drinking water (PCDW). The second angle was by

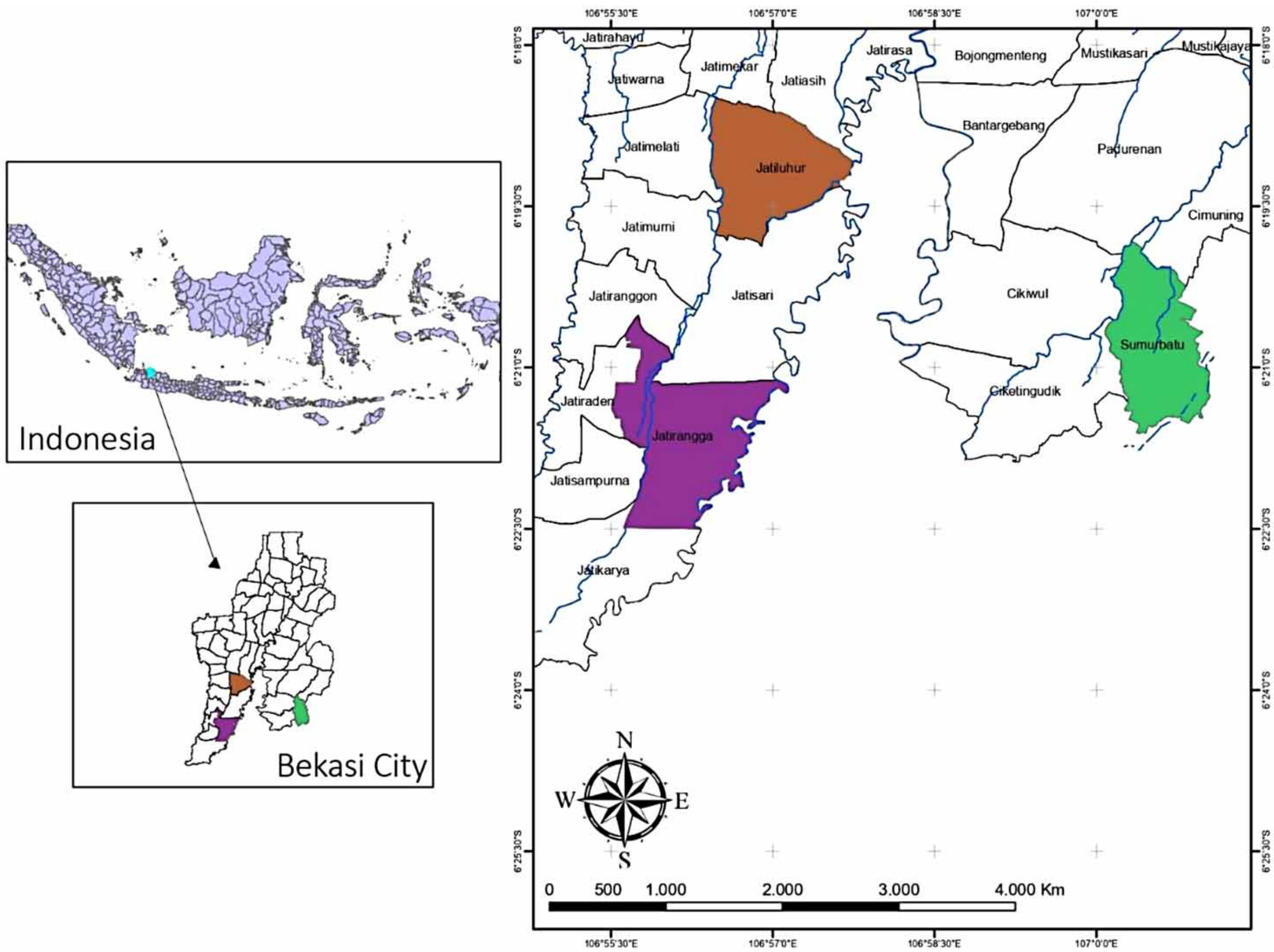


Figure 1 | Map of study location in three subdistricts in Bekasi City, Indonesia.

aggregating monthly data for temporal and seasonal trends over the year with the associated number of participating households each month. The number of households each month might not be constant due to participation withdrawal. The term 'water sources' in PWS, CWS, and PCWS includes water sources for all four activities (drinking water, coffee and tea, handwashing, and other domestic uses). Meanwhile, PDW and PCDW only consider water sources for drinking. Statistical analyses were performed using Student's *t*-test for parametric data and the Wilcoxon Signed Rank Test for non-parametric data. The third angle, when possible, included 1-year data from respondents with full or almost full participation (i.e., for at least 11 months; $n = 53$).

Water source and household perception were used as a basis for the categorization of the following:

- Improved and non-improved sources based on the JMP definition (WHO 2017).
- Self-supply source and non-self-supply source categories, where self-supply sources included boreholes, protected wells, and unprotected wells owned by individuals/households. Non-self-supply sources included water sources owned by a company or government and packaged water, such as an artesian well which in this case owned by the government, refill water, and bottled water.
- Drinking water perceived as safe (DWPS) was improved sources, on-premises, available, with household satisfaction in terms of safety, taste, appearance, smell, and reliability perception. Those perceptions were asked to the participating household every month by asking them to assess their drinking water condition (binary questions – good/not good) in terms of safety, taste, appearance, smell, and reliability (see Supplementary material, Appendix S1). This approach is also used by the Indonesian Government in their social and economic national survey (*Survey Sosial Ekonomi Nasional* or SUSENAS) to

estimate safely managed services in the absence of quantitative water quality testing. Households using DWPS can be defined as perceived as using safely managed water services considering the criteria of DWPS.

RESULTS

Background characteristics

Within the 87 households, the mean age of respondents was 40 years. Most of the respondents owned their houses, and occupations and educational levels varied. Almost half of the households (47%) had no occupation. The highest education of most households (30%) was primary school; 13% of households even had no school attendance. Most households (57%) fell into the lower-middle economic class based on wealth quintiles calculation (see Supplementary material, Appendix S3 for details of respondent characteristics).

Total rainfall between June 2020 and May 2021 was approximately 6,672 mm, with a median of 428 mm and an average of 556 mm (Supplementary material, Appendix S2) peaking on February 2022 (1,898 mm). Rainfall was lower than the median during June–September 2020 and November–December 2020. According to several data, including rainfall data in 2020 and 2021 (Supplementary material, Appendix S2), and the rainfall bulletin of June 2021 (BMKG 2021), seasonal data were analyzed by grouping the data from two periods: June 2020 to September 2020 as the dry season and October 2020 to May 2021 as the wet season.

Multiple water sources: temporal variation and household consistency

Of the 755 responses received over the 12-month period (Supplementary material, Appendix S4), a singular drinking water source was reported in 70% of responses while 30% used multiple drinking water sources ('all data' Figure 2(a) and Supplementary material, Appendix S5). The highest use of multiple water sources occurred during the month of May 2021 (Figure 2(a)) while multiple water sources for other activities were mostly used during the dry season, with 13–18% of house- holds using multiple water sources during the dry season compared to 7 −9% during the wet season. (Figure 2(a)-–(d)).

From a household perspective, 74% of the 53 households (respondents with full or almost full participation) used multiple drinking water sources throughout the year ('53HH1Y' Figure 2(a) and Supplementary material, Appendix S5) while 40–55% used multiple water source for the three other activities ('53HH1Y' Figure 2(b)–2(d) and Supplementary material, Appendix S5). When the water sources for the four activities were investigated altogether, almost two-thirds of the 53 households used multiple water sources (Figure 2(e), PCWS right side). This number is larger than the 32% of households that reported multiple water sources for their primary sources of the four activities (Figure 2(e), PWS left side), meaning that 32% of households resorted to other water sources as complementary for one or more activities.

Unimproved sources were still used as PDW sources 7% of the time (Figure 3(b)). Unimproved source use slightly decreased when complementary sources are considered (Figure 3(d)). Half of all data indicated multiple water use (51%) using boreholes as complementary sources, mostly for households with bottled water and refill water as their PDW source (Supplementary material, Appendix S6).

The variation in drinking water preference seemed to follow a seasonal trend. The choice of boreholes as sources of PDW was steady at a mean of about 47 $\pm$ 0.1% for the first 4 months (from June 2020 to September 2020) when it was dry but decreased to a mean of 41 $\pm$ 2.5% from November 2020 to May 2021 ($p < 0.05$; Supplementary material, Appendix S3). In the wet season, households switched from borehole water to bottled water, with a rise in the use of bottled water from 16 $\pm$ 2.8% from June 2020 to September 2020 to 18 $\pm$ 0.9% from October 2020 to May 2021 ($p > 0.05$; Supplementary material, Appendix S3). Many of these households still used borehole water as their complementary sources indicated by the increase in the wet season (Figure 4(b)).

There was a less marked seasonal shift of choice of boreholes and bottled water for other water uses besides drinking water. The proportions of borehole water being used for handwashing and for making tea and coffee were comparable in the wet and dry seasons, with yearly means of 77 and 66%, respectively ($p > 0.05$; Supplementary material, Appendix S3). Compared with other water sources, unprotected well use for the primary source of all activities constantly increased by 2–3% from the dry to wet season ($p < 0.05$; Supplementary material, Appendix S3).

Although both can be considered drinking water sources, the preference for water sources for making tea and coffee is not always the same as that for drinking water. Only 70% of the time, households opted for the same primary water source for drinking water and for making tea and coffee (Supplementary material, Appendix S6). More households chose to use other

Figure 2 | Percentages of household responses indicating 1, 2, and 3–4 water sources (WS) for various purposes (from top to bottom): (a) drinking water, (b) tea and coffee, (c) handwashing, (d) other domestic purposes, (e) in 53 households during 11–12 months for all four activities from drinking water to other domestic purposes with PWS only and PCWS. Graphs a–d contain 14 stacked bars. The first 12 bars represent percentage of monthly responses, the 13th bar represents all 755 data, and the 14th bar represents responses on a household level for the full year of the survey ($n = 53$ households).

sources besides packaged water for the latter activity, a total of 84% compared to only 54% of households not using packaged water for drinking water (Supplementary material, Appendix S3).

The primary water source for handwashing and other domestic purposes was the same 99% of the time (Supplementary material, Appendix S6). However, the complementary water source for these two activities was considerably different. From the 81 data where households had multiple water sources for other domestic use, 41% used different complementary sources/used complementary sources compared to handwashing with only 60 data of the use of multiple water sources (Supplementary material, Appendix S6).

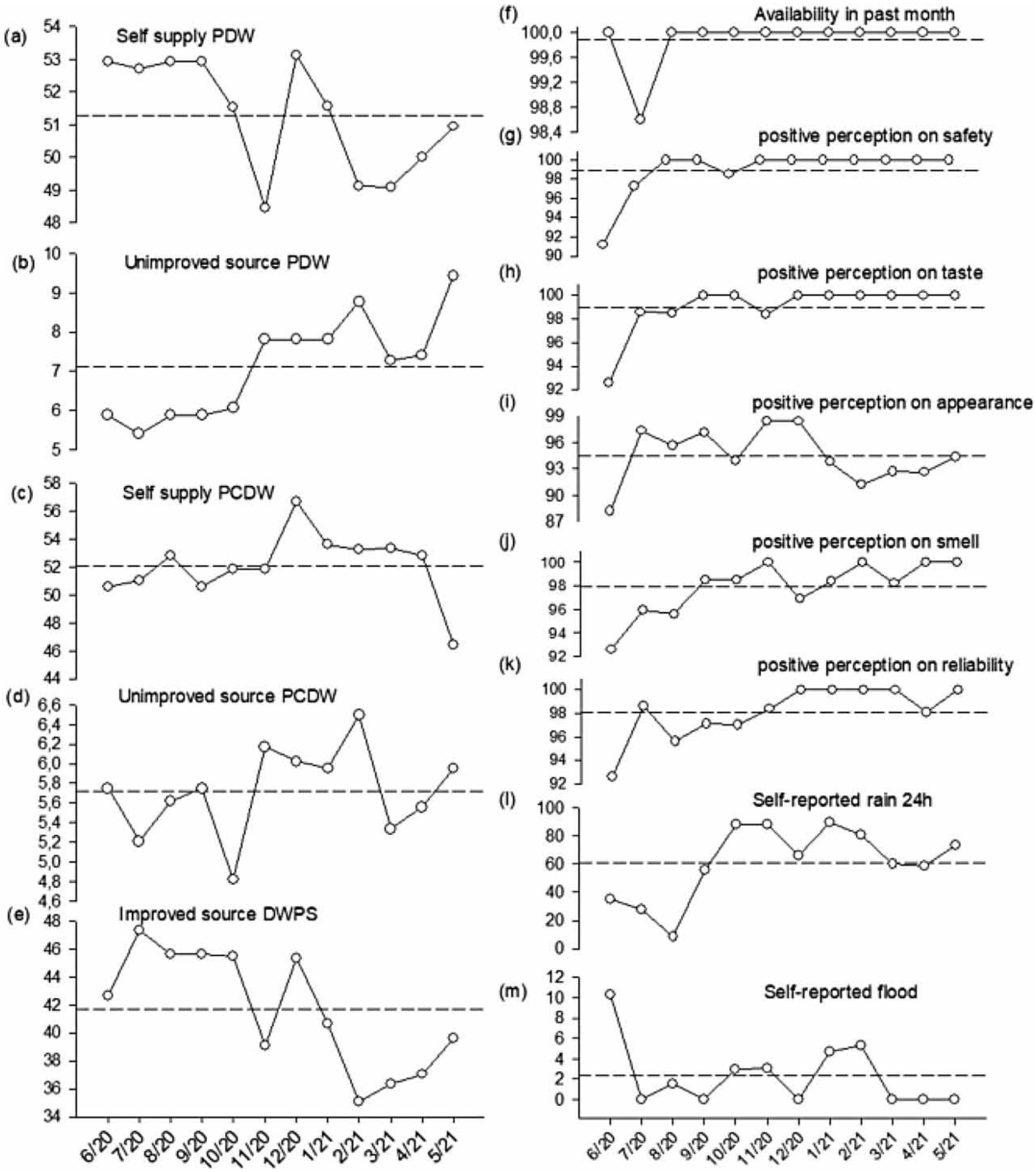


Figure 3 | Percentage of drinking water sources categories, perception rain, and flood monthly percentages of households (from top to bottom, left to right): (a) self-supply PDW, (b) unimproved source PDW, (c) self-supply all sources including PCDW, (d) unimproved source use of PCDW, (e) drinking water from an improved source and perceived as safe (DWPS), (f) reported uninterrupted water supply, (g–k) aspects of satisfaction with drinking water related to safety, taste, appearance, smell, and reliability, (l) reported rain in the last 24 h, and (m) reported flooding. Dash lines indicate an average of 755 data.

The mean use of self-supply for PDW source decreased overall from $52 \pm 0.7\%$ to $48 \pm 2.1\%$ ($p < 0.05$) in the wet season (Figure 3(a) Supplementary material, Appendix S3). The mean use of unimproved sources for PDW increased from $6 \pm 0.2\%$ to $8 \pm 0.9\%$ ($p < 0.05$) in the wet season (Figure 3(b) and Supplementary material, Appendix S3). However, when regarding CWS, self-supply users increased from $46 \pm 4.2\%$ to $59 \pm 9\%$ ($p < 0.05$) in the wet season while unimproved source users for PCDW were averaged at 6% (Figure 3(d)) with no significant difference between the wet and dry season ($p > 0.05$).

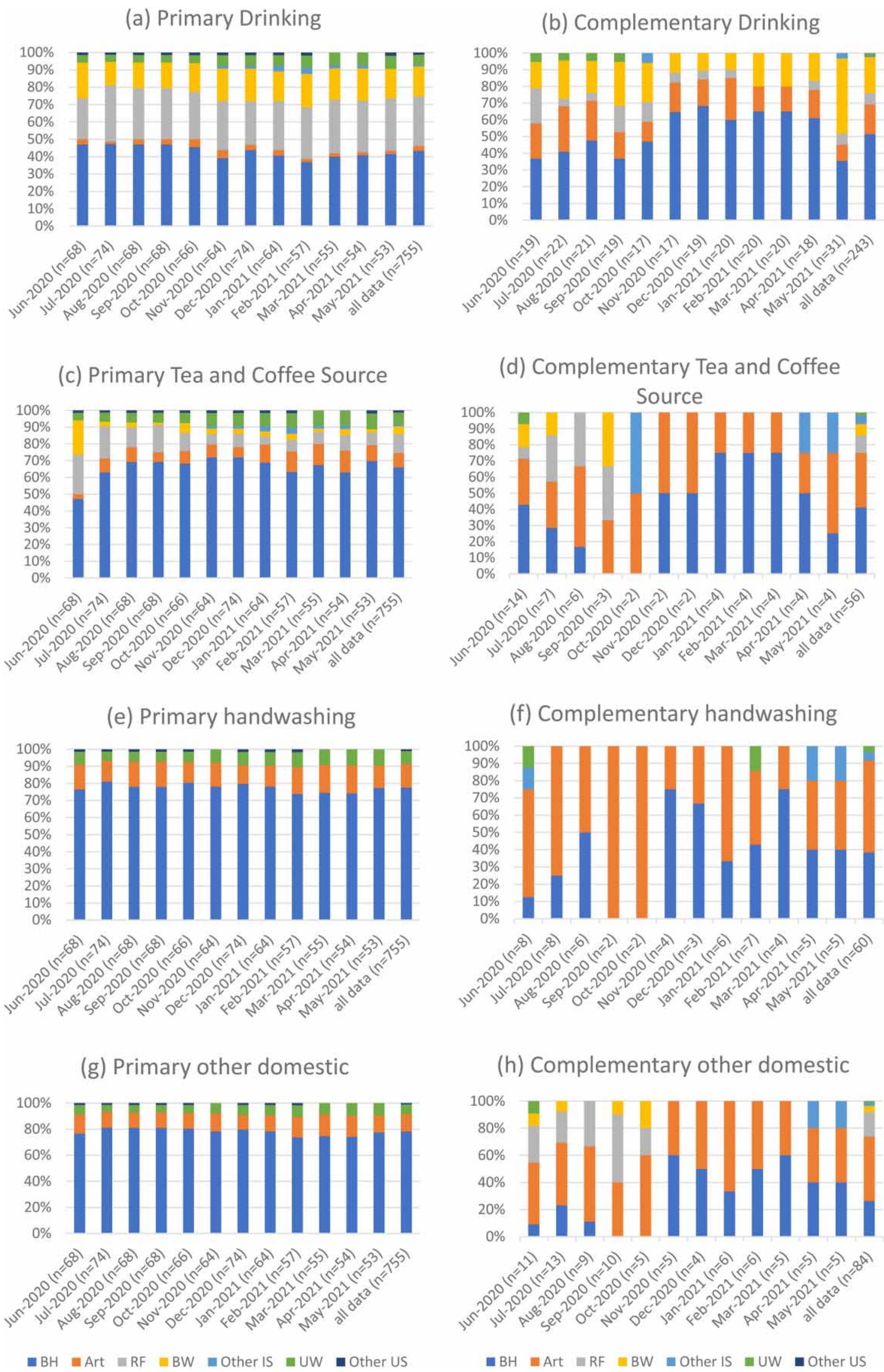


Figure 4 | Monthly percentages of primary water sources (left) and complementary water sources including second, third, and fourth sources (right) for various activities including (from top to bottom) (a and b) drinking, (c and d) tea and coffee, (e and f) handwashing, and (g and h) other domestic purposes. The first 12 bars represent the percentage of monthly responses. For figures of primary sources, the 13th bar represents all 755 data. For figures of complementary sources, the 13th bar represents all second, third, and fourth sources combined and total data varies depending on the number of complementary sources of each household at the given time.

Safety and perception

Overall, households were satisfied with their drinking water most of the time where the average positive perception on drinking water were more than 95% (Figure 3(g)–3(k) and Supplementary material, Appendix S7). Water sources used at the time of the interview were available almost 100% of the time. Unavailable water source was only recorded for one household in the month of July (dry season). The households also perceived their water safe with no issue with the taste for the most part, except in the first month of the survey (in the dry season) when 91 and 93% of respondents considered their water safe and with no taste, respectively. In the wet season, almost 100% of households considered their drinking water safe and without taste (Supplementary material, Appendix S3).

A few people had more issues regarding the smell, with a mean positive smell perception of 98% (Figure 3(j)). Issues regarding smell were reported in the dry and wet seasons, with mean perceptions of 96 and 99% in the dry season and wet season (Supplementary material, Appendix S3), respectively ($p > 0.05$). Households complained of an iron odor in the water (Supplementary material, Appendix S8). Over the 12 months, there were more issues regarding appearance, with a mean of around 94% irrespective of the season (Supplementary material, Appendix S3). The issues reported in the survey included turbid appearance, cloudiness, and settling particles in the water.

As sources changed throughout the year, the level of perceived water service level changed. There are 42% of households on average who has access to DWPS services, which is varied around 35–47% throughout the year (Supplementary material, Appendix S7). However, during the 12 months, only 25% of the 53 households had consistent access to DWPS services (Supplementary material, Appendix S7). Seasonal variation was also pronounced, as the proportion of households using DWPS or perceived using safely managed water services decreased from 45% in the dry season to 40% in the wet season ($p < 0.05$) (Figure 3(e) and Supplementary material, Appendix S3).

DISCUSSION

Results demonstrated the temporal variability of drinking water sources. More households used multiple water sources for drinking water than for other domestic purposes. This finding is similar with a study from Kumpel *et al.* (2017) in Nigeria, where there was consistency in the type of water source used for cooking and washing but the variability of drinking water sources.

There may be different reasons for the variations in water sources. However, some factors, mainly appearance, were often perceived negatively and became the basis for switching to other water sources, as observed by Wong (2009) who reported that people regarded visible contamination and turbidity as the two most important parameters in the assessment of drinking water quality (at 43 and 18%, respectively). Thus, water for making tea and coffee may come from sources perceived to be of less quality than drinking water sources because tea and coffee are prepared by boiling water with the final product being colored water, thereby making appearance less important.

Source switching to packaged water by seasonal factors is likely to be a determining factor in the choice of water source for households. The trend of self-supply use for drinking water in the dry season and switching to refill/bottled water in the wet season was similar to Nguyen *et al.* (2021) who reported decreasing use of higher-risk water sources during the dry season due to the deterioration of water quality, similar to our observation. Olonga *et al.* (2014) reported complaints of higher turbidity of borehole water in wet seasons which may be due to the higher infiltration and groundwater recharge in wet seasons. However, switching to packaged water during the wet season is not always the case, e.g., in Kumpel *et al.* (2017) where rainwater is preferable during the wet season and this reduced the use of bottled water. Thus, the seasonality of source switching must take into account the local context.

There are positive and negative outcomes of MWSU adoption. For households with limited piped water access and financial resources, MWSU is a fair solution as it builds resiliency to climate-induced water insecurity (Elliott *et al.* 2019). However, it may also drive households to supplement their water supply with water from unimproved sources (SUSU), which may increase their health risk (Daly *et al.* 2021). The practice of source switching based on climatic conditions has been correlated with the increase in diarrhea incidence in the wet season (Kulinkina *et al.* 2016b).

The findings of this study are also consistent with those of previous studies that call for regulators to weigh the cost and benefit of investigating complementary sources of drinking water (Foster & Willetts 2018; Daly *et al.* 2021). Such an exercise may reveal greater inequality and reliance on unimproved sources than the recorded figures (Adams & Smiley 2018). Moreover, water sources for other purposes, such as making tea and coffee, may be different than drinking water sources and may also require monitoring and evaluation in communities with water sources at high risk of fecal contamination. Although the water for tea and coffee is often boiled, it may still be at risk of contamination. Studies from Ghaudenson *et al.* (2021) in Bekasi and Metro City, Indonesia showed that boiling only reduced *Escherichia coli* contamination 70% of the time.

Even as multiple water sources may vary between and within households, it is impossible for regulators to cover all the temporal and spatial variations of MWSU. To reduce required resources, water quality monitoring and assessment may be risk-based (Charles & Greggio 2021). Investigations of multiple water sources should focus on households with high-risk profiles (Genter *et al.* 2021). In addition to households, risk assessment could also focus on vulnerable periods, such as during the shift from the dry season to the wet season (Kraay *et al.* 2020) and during the wet season as shown in this study and a previous study (Bain *et al.* 2021). Kraay *et al.* (2020) mentioned that the shift from the dry season to the wet season is the time when the pathogen concentrates to peak concentration and is ready for initial flushing to the environment and then a concentration–dilution process of the pathogen to the environment occurred in the rainy season.

It is acknowledged that this study is limited in several aspects. First, detailed reasons for switching sources and using multiple water sources were not investigated. Households only answered their perception of the current water source. Second, there is no water quality testing to describe household conditions related to safely managed water services. Finally, this study used self-reported data which might offer biased estimates. However, the breadth and depth of water sources across the year for four different activities are well covered and still support strong evidence of possible health risks from the water supply.

CONCLUSION

These results reveal the complexity of MWSU between and within households that is overlooked by the current monitoring program of safely managed drinking water. This longitudinal study yields critical information on monthly and seasonal variation and household preferences of water sources throughout the year that is not captured by the current literature. Households may use different water sources for different purposes which could also vary at different periods. CWS also vary according to uses and seasons, each of which may pose different health risks. Although resources are limited, future policies should be aimed at providing water services and ensuring consistent delivery of water services through multiple water sources throughout the year. Acknowledging the difficulty of assessing multiple water sources regularly, the available resources should be allocated for the monitoring of households, water sources, and periods associated with high risk.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

REFERENCES

Adams, E. A. & Smiley, S. L. 2018 Urban-rural water access inequalities in Malawi: implications for monitoring the sustainable development goals. *Natural Resources Forum* **42** (4), 217–226. https://doi.org/10.1111/1477-8947.12150.

Bain, R., Johnston, R., Khan, S., Hancioglu, A. & Slaymaker, T. 2021 Monitoring drinking water quality in nationally representative household surveys in low-and middle-income countries: cross-sectional analysis of 27 multiple indicator cluster surveys 2014–2020. *Environmental Health Perspectives* **129** (9). https://doi.org/10.1289/EHP8459.

Bappenas, POKJA Pembangunan Perumahan, Permukiman, Air Minum dan Sanitasi Nasional (PPAS) dan USAID IUWASH PLUS 2021 *Meta Data Target Indikator Air Minum*. Available from: https://www.iuwashtangguh.or.id/cms/wp-content/uploads/2021/05/Booklet-Meta-Data-Indikator-Air-Minum-v12-1.pdf.

BMKG 2021 *Buletin Hujan Bulanan di Indonesia – Updated Juni 2021*. Available from: https://www.bmkg.go.id/berita/?p=buletin-hujan-bulanan-di-indonesia-updated-juni-2021&lang=ID&tag=buletin-iklim.

BPS Kota Bekasi. 2021 *Kota Bekasi Dalam Angka 2021*. Available from: https://bekasikota.bps.go.id/publication/download.html?nrbvfeve=ZDkzZTc5MmFjOTJmOGIwMGI1MTNlYTJi&xzmn=aHR0cHM6Ly9iZWthc2lrb3RhLmJwcy5nby5pZC9wdWJsaWNhdGlvbi8yMDIxLzAyLzI2L2Q5M2U3OTJhYzkyZjhiMDBiNTEzZWEyYi9rb3RhLWJla2FzaS1kYWxhbS1hbmdrYS0yMDIxLmh0bWw%3D&twoadfnoarfeauf=MjAyMS0xMS0wMyAxMjozMjo1Mg%3D%3D.

Cassivi, A., Tilley, E., Waygood, O. & Dorea, C. 2021 Seasonal preferences and alternatives for domestic water sources: a prospective cohort study in Malawi. *ACS ES&T Water* **1** (6), 1464–1473. https://doi.org/10.1021/ACSESTWATER.1C00045.

Charles, K. J. & Greggio, E. 2021 Invited perspective: beyond national water quality surveys: improving water quality surveillance to achieve safe drinking water for all (sustainable development goal 6.1). *Environmental Health Perspectives* **129** (9). https://doi.org/10.1289/EHP10064.

Daly, S. W., Lowe, J., Hornsby, G. M. & Harris, A. R. 2021 Multiple water source use in low- and middle-income countries: a systematic review. *Journal of Water and Health* **19** (3), 370–392. https://doi.org/10.2166/WH.2021.205.

Elliott, M., Foster, T., MacDonald, M. C., Harris, A. R., Schwab, K. J. & Hadwen, W. L. 2019 Addressing how multiple household water sources and uses build water resilience and support sustainable development. *Npj Clean Water* **2** (1), 1–5. https://doi.org/10.1038/s41545-019-0031-4.

Foster, T. & Willetts, J. 2018 Multiple water source use in rural Vanuatu: are households choosing the safest option for drinking? *International Journal of Environmental Health Research* **28** (6), 579–589. https://doi.org/10.1080/09603123.2018.1491953.

Francisco, J. P. S. 2014 Why households buy bottled water: a survey of household perceptions in the Philippines. *International Journal of Consumer Studies* **38** (1), 98–103. https://doi.org/10.1111/IJCS.12069.

Genter, F., Willetts, J. & Foster, T. 2021 Faecal contamination of groundwater self-supply in low- and middle income countries: systematic review and meta-analysis. *Water Research* **201**, 117350. https://doi.org/10.1016/J.WATRES.2021.117350.

Ghaudenson, R., Priadi, C. R. & Foster, T. 2021 Effectiveness of groundwater boiling as household water treatment in Metro and Bekasi Cities, Indonesia. *E3S Web of Conferences* **277**, 04002. https://doi.org/10.1051/E3SCONF/202127704002.

Kraay, A. N. M., Man, O., Levy, M. C., Levy, K., Ionides, E. & Eisenberg, J. N. S. 2020 Understanding the impact of rainfall on diarrhea: testing the concentration-dilution hypothesis using a systematic review and meta-analysis. *Environmental Health Perspectives* **128** (12), 126001. https://doi.org/10.1289/EHP6181.

Kulinkina, A. v., Kosinski, K. C., Liss, A., Adjei, M. N., Ayamgah, G. A., Webb, P., Gute, D. M., Plummer, J. D. & Naumova, E. N. 2016a Piped water consumption in Ghana: a case study of temporal and spatial patterns of clean water demand relative to alternative water sources in rural small towns. *Science of The Total Environment* **559**, 291–301. https://doi.org/10.1016/J.SCITOTENV.2016.03.148.

Kulinkina, A. v., Mohan, V. R., Francis, M. R., Kattula, D., Sarkar, R., Plummer, J. D., Ward, H., Kang, G., Balraj, V. & Naumova, E. N. 2016b Seasonality of water quality and diarrheal disease counts in urban and rural settings in south India. *Scientific Reports* **6** (1), 1–12. https://doi.org/10.1038/srep20521.

Kumpel, E., Cock-Esteb, A., Duret, M., Waal, O. d. & Khush, R. 2017 Seasonal variation in drinking and domestic water sources and quality in Port Harcourt, Nigeria. *The American Journal of Tropical Medicine and Hygiene* **96** (2), 437–445. https://doi.org/10.4269/AJTMH.16-0175.

Maysarah, S., Putri, G. L., Pratama, M. A., Zulkarnain, F., Willetts, J., Foster, T., Genter, F., Harris, A. & Priadi, C. R. 2020 The occurrence of escherichia coli in groundwater of Bekasi City (Case study: Jatiluhur, Sumur Batu, and Jatirangga Urban Villages). *IOP Conference Series: Earth and Environmental Science* **566** (1), 012008. https://doi.org/10.1088/1755-1315/566/1/012008.

Nastiti, A., Sudradjat, A., Geerling, G. W., Smits, A. J. M., Roosmini, D. & Muntalif, B. S. 2017 The effect of physical accessibility and service level of water supply on economic accessibility: a case study of Bandung City. *Indonesia. Water International* **42** (7), 831–851. https://doi.org/10.1080/02508060.2017.1373323.

Neumann, L. E., Moglia, M., Cook, S., Nguyen, M. N., Sharma, A. K., Nguyen, T. H. & Nguyen, B. v. 2013 Water use, sanitation and health in a fragmented urban water system: case study and household survey. *Urban Water Journal* **11** (3), 198–210. https://doi.org/10.1080/1573062X.2013.768685.

Nguyen, K. H., Operario, D. J., Nyathi, M. E., Hill, C. L., Smith, J. A., Guerrant, R. L., Samie, A., Dillingham, R. A., Bessong, P. O. & Rogawski McQuade, E. T. 2021 Seasonality of drinking water sources and the impact of drinking water source on enteric infections among children in Limpopo, South Africa. *International Journal of Hygiene and Environmental Health* **231**, 113640. https://doi.org/10.1016/J.IJHEH.2020.113640.

Olonga, O. R., Ndunda, E. & Makokha, M. 2014 Seasonal variations of physico-chemical and microbiological characteristics of groundwater quality in Ruiru, Kiambu county, Kenya. *International Journal of Scientific and Research Publications* **5** (12). Available from: www.ijsrp.org.

Shaheed, A., Orgill, J., Ratana, C., Montgomery, M. A., Jeuland, M. A. & Brown, J. 2014 Water quality risks of 'improved' water sources: evidence from Cambodia. *Tropical Medicine & International Health* **19** (2), 186–194. https://doi.org/10.1111/TMI.12229.

Vedachalam, S., MacDonald, L. H., Shiferaw, S., Seme, A., Schwab, K. J. on behalf of PMA2020 investigators 2017 Underreporting of high-risk water and sanitation practices undermines progress on global targets. *PLOS ONE* **12** (5), e0176272. https://doi.org/10.1371/journal.pone.0176272.

WHO 2017 *Safely Managed Drinking Water – Thematic Report on Drinking Water 2017*.

WHO/UNICEF 2020 *Joint Monitoring Programme for Water Supply, Sanitation and Hygiene – Data Tables*. Available from: https://washdata.org/data/household#!/table.

Wong, S. T. 2009 Source choice perception and sustainable rural water supply development: a case study of Ban Thadindam, Lopburi, Thailand. *Water International* **25** (4), 586–594. https://doi.org/10.1080/02508060008686874.

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