Household Water Supply Strategies in Urban Bandung, Indonesia: Findings and Implications for Future Water Access Reporting

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Abstract. Through structured interviews and statistical analyses, this study investigated access to water and strategies of 1227 vulnerable households in Bandung, Indonesia. The use of mixed water sources, household water treatment, and home storage suggest low trust in improved sources, and compromised safety and reliability of water. While official statistics suggest a high level of access to improved water sources, full-time access to such sources is overestimated. Integration of user behavior into the new monitoring approach for the water supply sector in the post-2015 development framework is proposed.

Keywords: *household water treatment and storage; MDGs; mixed water sources; monitoring; SDGs; water supply.*

1 Introduction

Using the indicator of access, one hundred and sixteen countries globally have achieved the drinking water target of the Millennium Development Goals (MDGs) [1]. There has been a wide concern that access does not always result in water safety and sustainability as mentioned in Target 7c of the MDGs. Although 89% of the developing world's population has gained access to improved water sources [2], service quality problems have yet to be resolved.

Water supply is one of the main problems in urban areas. The size of the urban population poses an enormous challenge to water provision through an increase in clean water demand. Ninety-six percent of urban populations have access to improved water sources [2] but the problems of poor water quality, interrupted

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service, insufficient disinfection, and infrastructure ageing and damage remain [3]. Urban dwellers are often forced to rely on more expensive water sources, such as bottled water, or more polluted sources. Half of the urban households in Indonesia rely on groundwater without extraction fee [4], which may be polluted. Although about three-quarters of the urban households use pour-flush toilets, very few households are connected to a safe wastewater disposal system [5]. The high rate of enteric contamination of water sources reflects the poor sanitation facilities in Indonesia. For example, a study suggests that *E. coli* found in Jakarta's drinking water samples, mostly water extracted from boreholes, is mainly because wastewater discharges infiltrate the city's groundwater sources [6].

Urban water problems are partly driven by increasing demographic pressures, such as rural-urban migration and distorted rural-urban fringes. Indonesia has experienced a steady urbanization, which is projected to contribute 50 million urban inhabitants between 2014 and 2050 [7]. This growth is expected to be concentrated in cities such as Jakarta and Bandung [8]. With a total population of almost 2.5 million, Bandung City attracts tourists and job seekers alike; thus, rapid population growth in Bandung is inevitable. A major improvement in water supply provision, for which the city government is responsible, must accompany this growth. Nevertheless, governance failures in drinking water service provision for the low-income community in urban Bandung have been documented [9]. These failures are reflected by limited piped-water service availability; inadequate quality, quantity, and continuity of water; a high-cost burden to the poor; illegal connections; and low trust in public service providers. The lack of reliable water services in Bandung leads to an excessive withdrawal of groundwater, which in turn threatens its sustainability and causes land subsidence problems [10].

Using the case of Bandung, this paper aims to understand the strategies of vulnerable urban households to secure access to a safe and adequate supply of water. This study also explored the two sides of a coin in drinking water supply: access and service quality. This study is descriptive in nature and is one of only a few that have investigated user strategies and monitoring in depth (for an exception see [11])]. This study further discusses recommendations to incorporate user strategies of securing access to safe water into the water supply monitoring approach of the post-2015 development framework.

2 Methods

This study focused on two types of vulnerable populations in Bandung City, West Java Province, Indonesia: slum and riverbank dwellers.

2.1 Slum Households

Slum areas are a national priority for the Acceleration Program of the National MDGs' Target Achievement [12]. This study interviewed 127 out of 30,281 slum households distributed into five districts – Andir (n=23), Sumur Bandung (n=16), Rancasari (n=24), Bojongloa Kidul (n=27), and Cibeunying Kidul (n=37). Participants were selected through a representative and proportional-to-size sampling. The total number of slum households in Bandung City was obtained from the Information System and Database of Urban Slum Areas of the Directorate General of Public Works Year 2009 [13].

The number of samples was determined based on Yamane's formula, a commonly used simplified approach in representative sampling, assuming a 95% confidence level with a 10% margin of error [14-16]. A two-stage cluster method was also used to select samples [17]. The first sampling unit consisted of districts in which slum communities are located. These districts are listed in the Decree of the Mayor of Bandung City Year 2010 [18]. Slum neighborhoods within each district were selected as the second sampling unit, from which households were chosen by random walk and quota sampling [19].

2.2 Riverbank Households

The riverbank household survey was completed as part of the Drinking Water Safety Plan Pilot Project commenced by the Drinking Water and Sanitation Policy (WASPOLA) Facility and the Sanitation Working Group of Bandung City. The WASPOLA Facility is an implementation project of community-based drinking water and sanitation policy and institutional-based drinking water and sanitation policy in Indonesia. Meanwhile, the Sanitation Working Group is an ad hoc organization established as a communication and coordination forum between various governmental agencies in the water and sanitation sector. This secondary data set was included in this study since riverbank dwellers represent both socio-economic and geographic vulnerabilities. Through a representative and proportional-to-size sampling, this study employed data from 1100 out of 11,471 riverbank households along the Cikapundung River. Samples were distributed into three primary target districts for the Water Safety Plan Pilot Project: Coblong (n=643), Bandung Wetan (n=267), and Cidadap (n=190). From each village within the districts, clusters of community groups were selected from the population registry of the Municipal Statistical Agency.

The slum household survey collected data on demographic information, socio-economic status (age; sex; household member; education level; occupation; ownership status of housing; type of housing; duration of residency; electricity power installed in housing; income; expenditure), basic health services (payment for healthcare; type of healthcare facilities frequently visited), existing water and sanitation services, strategies for obtaining desired levels of service, as well as knowledge, attitudes, and practices concerning water, and self-reported illnesses. The riverbank household survey collected data on the demographic information, socio-economic condition of households (age; sex; occupation; marriage status; education level; status of ownership of housing; electricity capacity installed in housing; housing size; housing type; income), self-reported illness, and access to and use of their water sources.

The monthly income data in the slum household survey are based on the Minimum Regional Salary 2011 of Bandung City [20]. The Regional Minimum Salary is a standard for industries that stipulates the minimum monthly salary for unmarried laborers. Meanwhile, the riverbank household survey did not use this classification. In both surveys, closed-ended questionnaires were used, enumerators were carefully trained, and questions were asked verbally to respondents to avoid bias. The surveys were voluntary and did not contain information that would personally identify the respondents. Informed consent was given prior to the interview and respondents who were willing to participate had the right to withdraw at any time during the interview. Data from the survey were statistically analyzed with a descriptive method using IBM® SPSS Statistics Version 21.

3 Results

3.1 Household Vulnerability

Riverbank areas are vulnerable to flooding and pollution, and this exposes the people who live there to these hazards, while slum households are vulnerable because of the poor basic service situations they are currently living in. Table 1 depicts the socio-economic profiles of the households in this study. On average, two families of different generations shared the same property in the slum households. Meanwhile, the overall mean household size for the riverbank area was five persons. The majority of the heads of households living in the slum area were primary and secondary school graduates. Only a small fraction of respondents and heads of households pursued higher education levels. A low education level may affect socioeconomic status by reducing the opportunity for better income. Sixty-two percent of the heads of households attained secondary school or lower and were reported to have a monthly income under the Minimum Regional Salary Year 2011. Only 38% of the heads of households attained high school or higher education and were reported to have a monthly income lower than the Minimum Regional Salary.

Access to healthcare services may also affect the vulnerability of households. The survey revealed that 50% of slum respondents preferred public health clinics and 23% preferred private practices to seek healthcare services. Healthcare costs mainly drive the high preference towards public health clinics, as only 21% of the slum respondents were covered by health insurance. High out-of-pocket health expenditures, together with lack of adequate water and sanitation service, will put households at greater risk of health and economic impact. A majority of respondents were found to have a secure tenure and live in their own permanent house. According to the Local Government Asset Map [21], the areas selected in the slum household survey were not state-owned land. Meanwhile, only 0.9% of the riverbank households interviewed had a vague status of ownership suggesting that they may live on state-owned land. Thus, the water supply problems confronted by the majority of the respondents were caused by poor service delivery rather than legal exclusion issues [22].

3.2 Household Strategies in Securing Access to Safe Water

3.2.1 The Use of Mixed Water Sources

Respondents used various piped and non-piped water sources. The types of water sources found in the slum households are piped water on premises, public tap, borehole, protected dug well, protected spring, water from vendors, and branded and non-branded bottled water. Non-branded bottled water produced in small refilling stations has gained popularity since the last decade in Indonesia, as a cheaper alternative to the more expensive branded bottled water. Meanwhile, the riverbank households used piped water on premises, public tap, wells (borehole/dug well), spring water, bottled water, river water, and rain water. Figure 1 presents the levels of access to these water sources for each district in the slum and riverbank areas.

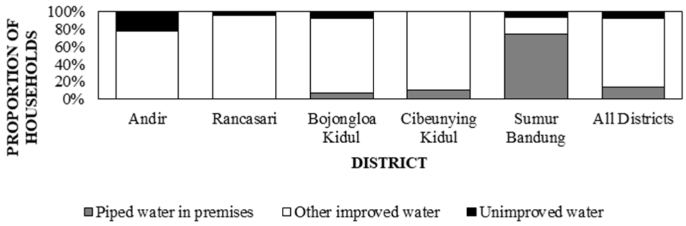
Access to water in the slum households was classified based on the three-step ladder of the Joint Monitoring Program (JMP), which consist of piped water on premises, and other improved and unimproved sources [24]. In the slum households, the levels of access to piped water, other improved water sources, and unimproved water sources were 14%, 80%, and 6%, respectively. Meanwhile, access to water in the riverbank households was classified as piped and non-piped sources. Out of 1100 riverbank households, piped water (45%) and groundwater (40%) were the most commonly used water sources. The fact that no riverbank household used water from vendors does not represent a lesser preference for the source; householders stated that the topographical contour prevents water vendors from selling water in those areas.

Table 1 Socio-economic profile of respondents and households in slum areas (n=127) and riverbank areas (n=1100).

Component	Slum household		Riverbank household	
Average age of respondent	41 years old		45 years old	
Sex of respondent	Male	11.8%	Male	31.5%
	Female	88.2%	Female	68.5%
Marriage status of respondent	Married	87.4%	Married	91%
	Not married	3.1%	Not married	0.7%
	Divorced	1.6%	Divorced	8.3%
Position within the family	Head of household	17.3%	Head of household	33.3%
	Household member	82.7%	Household member	66.7%
Education of respondent	Unschooled	7.1%	Unschooled	3.7%
	Primary school	38.6%	Primary school	32.1%
	Secondary school	27.6%	Secondary school	21.6%
	Highschool	26%	Highschool	35.6%
	University/college	8%	University/college	7%
Average number of (a) families in one house, and (b) person in one household	(a) 2 household (b) N/A		(a) N/A (b) 5 person	
Type of housing	Permanent	87.4%	Permanent	79.1%
	Semi/non-permanent	12.6%	Semi/non-permanent	20.9%
Housing ownership	Owned by respondent	72.4%	Owned by respondent	68.5%
	Not owned by respondent	27.6%	Not owned by respondent	31.5%
Monthly Household Income	< IDR 1,188,435 (≤ US$ 125)	53.5%	< IDR 1,000,000 (<US$104)	37.9%
	≥ IDR 1,188,435 or ≥US$ 125	46.5%	≥ IDR 1,000,000 (≥US$104)	62.1%
Most visited health facilities	Public health center	59.1%	N/A	
	Private practice	22.8%		
	Clinic/hospitals	13.4%		
	Others	4.7%		
Source of health expenditure	Out-of-pocket expenditure	75.6%	N/A	
	Insurance/employer	24.4%		

Notes: Indonesia uses the term 'household' to represent a nuclear family registered in local registries. Higher education attainment includes universities, academies, colleges, seminaries, and institutes of technology. 'N/A' means not asked in the questionnaire. IDR 1,188,435 is the Minimum Regional Salary for Bandung City for 2011 as stipulated in the Minimum Salary in the Regencies/Municipalities in West Java Year 2011. US$ 1= IDR 9,124 based on the Bank of Indonesia's conversion rate in November 2011.

In-house piped water connections supplied by the Municipal Water Company (MWC) of Bandung City were only available in three out of five districts of the slum households. Piped water was largely present in Sumur Bandung and Cibeunying Kidul, which are located in the city center and relatively close to the MWC's main water treatment plant. From the 109 slum households that did not have access to piped water, 28% stated that they were interested in having a connection, while 72% refused to have a connection, indicating a low trust in piped water providers. The three riverbank districts surveyed were included in MWC's service area, but access to piped water was less than 50%. Bandung City has determined a minimum service standard target of 120 liter per capita per day [25]. With MWC's production capacity of 2,478 L per second and the city's standard minimum service of 120 L per capita per day, MWC can serve more than 72% of the population. However, only roughly 30% of the total population of 2.5 million is served by piped water on premises. According to the Indonesian Association of Municipal Water Companies (BPPSPAM), the average water loss for Bandung City in 2014 was 32.2%.



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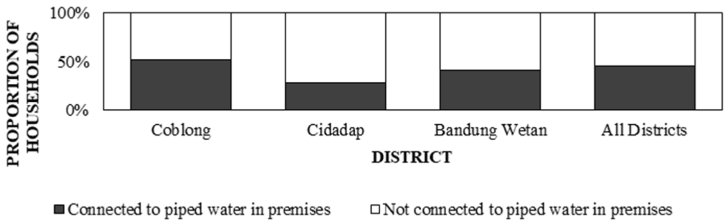

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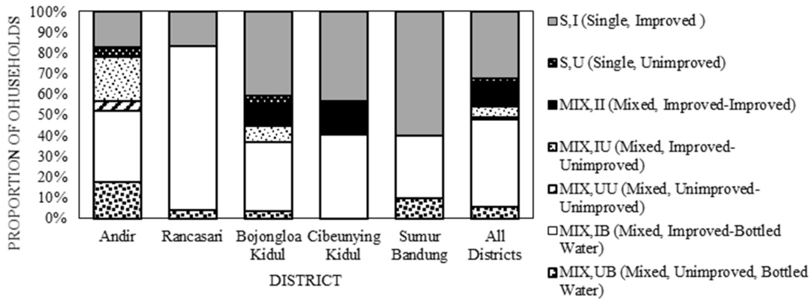
Figure 1 (a) Access to water based on JMP's water ladder in the slum households in five subdistricts (n=127); (b) access to water in the riverbank households based on piped/non-piped classification.

As shown in Figure 1, slum households that solely rely on one or more unimproved water sources were counted as not having access. Ninety-four percent of slum respondents had access to one or more improved water sources. Meanwhile, in the riverbank households, only 26% used a non-piped source and 14% used piped water without mixing it with other water sources. In the slum households, 66% of respondents used mixed water sources. Respondents used piped water together with groundwater, public taps or bottled water. Households without access to piped water rely heavily on boreholes and bottled water. Thus, although the level of access to improved water sources seems high, the overall percentage of households that uses unimproved water sources was 56%.

Figure 2 elaborates on the use of single and mixed water sources in the slum and riverbank households. In the slum and riverbank areas, only 34% and 39% of households used single water source, respectively. The majority of households used multiple water sources, often combining improved and unimproved water sources or piped and non-piped water sources. In the slum area, 50% of groundwater users used bottled water for drinking, while in the riverbank areas, 62% and 54% of piped water users and groundwater users, respectively, used bottled water. This illustrates the popularity of bottled water as the main drinking source. Figure 3 illustrates the specific use of each water source in the slum and riverbank households. The majority of households with access to piped water were prepared to use the water for drinking and cooking. Meanwhile, households with access to other improved water sources, such as boreholes and protected dug wells, are less inclined to use the water for such purposes.



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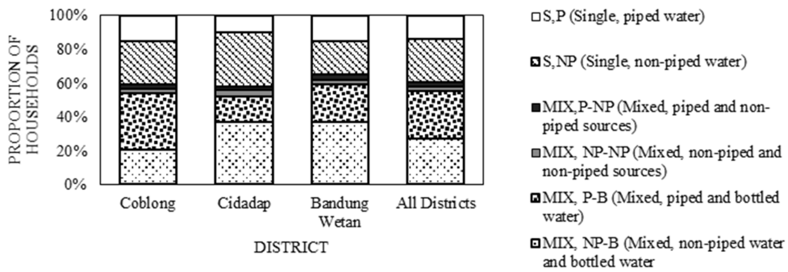

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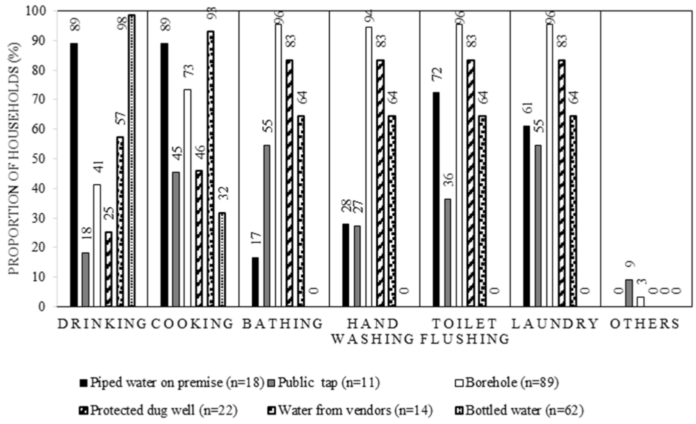
Figure 2 The use of mixed water sources within: (a) the slum households (n=127) and (b) the riverbank households (n=1100). Piped water is classified as an ‘improved source’ for slum household survey.



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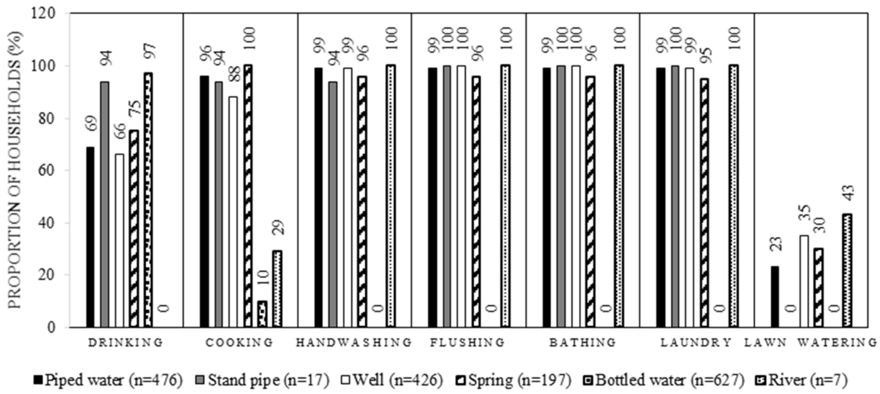

(b)

Figure 3 Specific water uses by households in: (a) the slum households and (b) the riverbank households. (Note: n represents number of households having access to each water source; one household can have access to more than one source of water).

3.2.2 Household Water Treatment and Storage

Despite the high level of access to improved sources in slum households, water quality from these sources remains a question. Figure 4 shows household water treatment strategies performed by slum dwellers to obtain the desired level of quality. Information regarding individual household water treatment was asked through the questionnaire. More than 60% of piped water users and 50% of those having access to other improved water sources performed household water treatment measures. Meanwhile, the proportion of users of unimproved water that performed household water treatment was low, probably because bottled water is the most commonly used type of drinking water source.

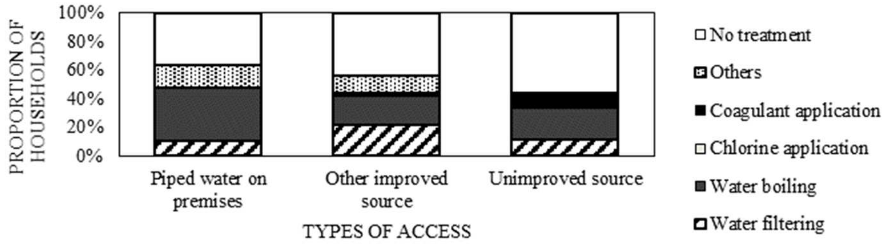

Figure 4 Household water treatment in the slum households based on the JMP's water ladder (n=127).

Water boiling was the most preferred method of disinfection amongst the slum households, particularly amongst piped water users. Householders were not familiar with the disinfection properties of chlorine; only 54% of respondents stated that chlorine can kill pathogens in water. The attitude of respondents toward various household water treatments also confirmed these findings. More than 90% of the respondents agreed that boiling water can improve water quality, and only half of the respondents agreed that water quality improvement could also be achieved through water filtration, the use of coagulants, or chlorine application.

Slum respondents also employed water storage strategies. Sixty-six percent of slum households preferred to store water because of continuity issues. Figure 5 shows water continuity in the slum households during the dry season. Only less than 30% of piped water users experienced reliable service for 24 hours a day; the remaining 70% of piped water users only had access for four to twelve hours per day. The continuity issue also applied to unimproved water sources if water vendors were the main suppliers of water. However, household water storage can also pose potential water-related health risks if it is not safely performed.

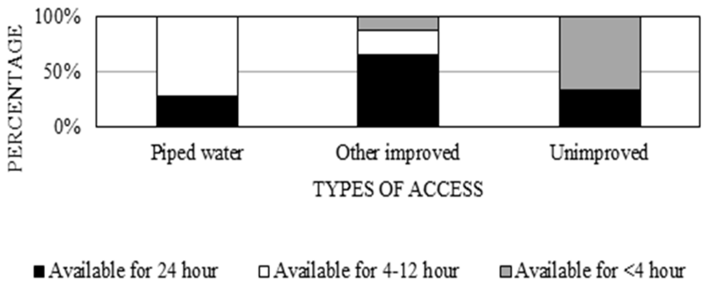

Figure 5 Continuity of drinking water sources in the slum households during the dry season (n=127).

The knowledge, attitude, and practice survey revealed that a majority of respondents were aware of the water contamination risk associated with storing water in open containers. More than 90% of slum respondents were aware that open water storage carries the risk of contact with rats and provides a breeding place for disease vectors. In spite of these contamination risks, as many as 40% of the households continued to use open containers for storing water at home.

3.2.3 Potential Health Impacts of Water, Household Strategies, and Safe Sewage Disposal

In the slum household survey, a Chi-square test was performed to determine the correlation between type of access to water (piped water, improved, and unimproved) and reported illnesses. There was no significant association between the types of access available with self-reported diarrhea incidences in the last one month (p=0.193) and self-reported skin diseases in the last one month (p=0.618). In the Cikapundung households, Fisher's exact test was performed to determine the correlation between the type of access to water (piped water and non-piped water sources) and the reported illnesses in the last six months. There was a significant association between the use of piped water on premises with self-reported diarrhea incidences (p=0.00). However, there was no significant association between the use of piped water on premises and self-reported skin diseases (p=655).

Figure 6 explores the links between diarrhea, access to water and household treatment. The rate of self-reported diarrhea was calculated for each category as the number of participants reporting diarrhea divided by the total number of participants [30]. The rate of self-reported diarrhea was the lowest for households with the highest level of household treatment. In contrary, households with a lower level of home treatment adoption, although using more than one improved water source, had a higher rate of self-reported diarrhea. Bottled water users had a lower rate of self-reported diarrhea compared to non-bottled water users who perform low level household water treatment. Slum respondents were also asked if they were connected to a safe sewage disposal facility.

Cross-contamination of water sources and wastewater was prevented in 37.8% of households through pit latrine (1%), municipal sewage treatment facility (4%), and communal or individual septic tank (33%). Meanwhile, 58% of slum respondents had no connection to a sewerage system or on-site wastewater treatment facilities, such as a safe latrine or septic tank. Furthermore, open defecation is still performed in the Rancasari District. Figure 6 shows that almost all households with different types of access to water had less than 50% coverage of safe sewage disposal.

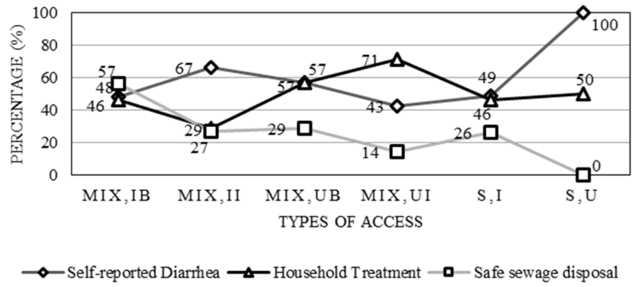

Figure 6 The rate of self-reported diarrhoea, the percentage of households performing home water treatment, and the percentage of households with safe sewage disposal in the slum households based on type of access (MIX,IB: mixed sources, improved-bottled water; MIX,II: mixed sources, improved-improved; MIX,UB: mixed sources, unimproved-bottled water; MIX,UI: mixed sources, improved-unimproved, S,I: single-source, improved; S,U: single-source, unimproved water). Piped water is classified as an improved source (n=127).

4 Discussion

4.1 Challenges to Improve Access and Service Quality

The previous sections have demonstrated the coping strategies of vulnerable urban households and the potential health impact resulting from combinations of water access and treatment strategies. The findings on different household strategies to obtain a safe and reliable supply of water confirm previous studies [11,30,31-33].

Access to improved water sources in the slum households exceeded the target of the national MDGs for improved urban drinking water (7%) and was only six percent below the 2019 universal access target formulated by the Government of Indonesia. Caution, however, has to be taken when using this access level estimate, which ignores the combined use of improved and unimproved sources by households. Meanwhile, the access to piped water of the riverbank households was much higher than that of the slum households. The reasons may be twofold: all the riverbank districts are located close to MWC's main network and more riverbank households may be able to afford a water connection compared to the slum households.

Despite high access to so-called improved water sources, vulnerable households are struggling to resolve the problems of poor service quality, where the safety and reliability of household water sources are still compromised. Although the quantity and continuity of water from boreholes may be quite reliable, the perception of poor water quality may discourage respondents to use groundwater for drinking. Respondents preferred bottled water despite its higher prices when compared to that of improved sources. A high preference for bottled water was observed in both the slum and riverbank households. With regard to piped water, many of the vulnerable households do not have access to an uninterrupted piped water supply that has undergone a full-range treatment to eliminate microbial, physical and chemical agents. When piped water supply is available, most households refuse to directly drink the water without boiling it first. The efficacy of boiling has been investigated; households that do not boil water have a higher water contamination risk compared to those who do [28]. Although the rise of fuel prices makes boiling water more costly compared to other treatment methods, these hidden costs are neglected. The installation of water filters is perceived to require a high capital cost and is commonly only used by middle-to-high-income borehole users.

The slum household surveys also revealed that the households receiving water from unimproved sources are the households least likely to engage in point-of-use household water treatments. This may be explained by the high use of bottled water as a form of unimproved source among households. Note that bottled water is considered 'improved' only if water for other domestic purposes originates from some kind of improved source. This behavior signals the lack of trust in water quality and the concern of re-contamination in the deteriorating distribution networks. Studies confirmed that bottled water is often preferred over tap water and perceptions of water quality drive the drinking preference of consumers [34,35].

Bottled water markets are growing rapidly in urban Indonesia; one can find a range of products from multi-national brands to the ones available in small refill water kiosks. The majority of slum respondents stated that water quality is the main reason for using mixed water sources or unimproved water sources. For drinking purpose they rely on bottled water, which is considered safer. The trust in water quality and the ease of use perhaps explain the increasing popularity of bottled water among low-income households. However, branded bottled water is three to five times more expensive than refill bottled water, thus refill water kiosks are more commonly used by low-income households. As the most preferable choice of drinking water, refill bottled water has obtained a high trust among its customers, quality-wise. This refill water should also comply with the quality standard for drinking water and water quality tests and sanitary inspections must be conducted to ensure its safety [23]. A health concern may arise since health risks related to the consumption of refill bottled water are present. Many refill water kiosks are not certified by local health agencies, which means that inspection of water quality is rarely performed, if at all. The emerging numbers of unregistered refilling stations can pose a significant threat to consumers' health if regulators fail to ensure that they meet the safety standard for drinking water. Refill water kiosk owners may be negligent in terms of best hygiene practices and not properly sterilize 19-liter water bottles prior to reuse. Studies have found that in many instances, refill bottled water in Indonesian cities is contaminated by coliform bacteria [26,27]. Thus, measures are necessary to ensure the safety of refill bottled water.

The significant association between the rate of self-reported diarrhea and the use of piped water in the Cikapundung Basin suggests that having piped water may protect people’s health. But since in this area those who have piped water also buy bottled water and come from higher income levels, it is difficult to control the effect of such confounding variables in this kind of study. Also, improved water sources are not necessarily safe [36]. The authors further suggest that microbiological risks among households with access to improved water sources are contributed by water storage, risks specific to water supplies, and household water management practices. Figure 6 suggests that fecal materials are dumped daily into receiving water bodies. Although this study did not cover water quality analysis, it is expected that inadequate sanitation facilities pose contamination risk of groundwater, which is used as the main water source by the majority of households in Bandung. The rate of self-reported diarrhea seems to be lower in households with a higher level of water treatment, although the connection to a safe sewage disposal system is low. The effect of poor sanitation on health may be negated by the use of bottled water and household water treatment strategies. The health risk in these households is probably prevented by the use of bottled water with a more trusted quality compared to other sources used without treatment. Even so, as previously discussed, the risk of consuming loosely regulated refill bottled water cannot be neglected.

This study found that households refuse to drink ‘uncooked’ piped water due to the poor perception of water quality, invest in several means of household water treatment, and sustain open-container storage practices. These behaviors suggest that risk of contamination at the point-of-use exist. All bacterial contaminations of drinking water occur as post-source contamination instigated during storage in households [29]. Safe storage and household water treatment interventions may improve water quality in slum areas [29]. Thus, guidelines for household water treatment and safe water storage as prominent practices in slum areas should be disseminated. Even so, this would not replace the main responsibility of maintaining water supply facilities that provide a safe and reliable supply of water.

The binary water problems revealed in this study imply that to achieve universal access to water, new infrastructure expansion to keep up with urban growth as well as renovations of the existing infrastructure to maintain the desired level of access are crucial [37]. A significant investment in piped water networks is required to avoid increasing the loss of access to acceptable service [38]. A high percentage of piped water users prefer alternative drinking water sources or invest in household treatment strategies. Thus, piped water suppliers are suggested to improve treatment efficacy and protection in the distribution network. Effective resource allocation, not only to build new connections but also to repair and maintain existing ones, is needed.

4.2 Implications for Policy and Monitoring

4.2.1 The Use of Mixed Water Sources and the Domestic Water Mix Optimization (DWMO) policy

The use of mixed water sources among slum households, particularly the combination of improved and unimproved water sources, suggests that the actual percentage of households having access to improved water sources on full-time bases is overestimated. The use of mixed water sources has been a common practice in Indonesia and more specifically in Bandung. Nevertheless, policy documents did not officially recognize this practice until the WASPOLA Facility proposed the Domestic Water Mix Optimization (DWMO) policy [39]. With the principle of 'every drop of water counts' as its core, this strategy strives to improve efficiency and effectiveness of domestic water provision through an optimization of various types of water sources, demand management, and water quality for specific uses.

DWMO groups divide domestic water into four classes of use: human consumption, hygiene, toilet flushing, and outdoor use. These uses have different water quality requirements. As scholars argue, it does not make any sense to use drinkable water for toilet flushing [32]. Although the DWMO policy will be extremely useful in rural or low-density areas in which centralized water supply may be less effective, the DWMO scheme must be carried out with discretion in urban areas. It does not provide an argument to shift away from networked service expansion.

Having been piloted in Bandung, this strategy, which was mainstreamed into the 2015-2019 Indonesian Midterm National Development Plan, is still in its infancy. Recently, the WASPOLA Facility has developed a tool for local governments for selecting the most efficient household water sources. An earlier recommendation from WASPOLA to the DWMO scheme was to discourage the use of bottled water since it produces a high cost burden to poor households. The high dependency on such an unsustainable drinking water source signals the failure of water supply provision. Moreover, the DWMO scheme highly depends on the attitude and perception of what is considered 'safe water', which may be viewed differently by policy makers and users. For example, the high trust in refill water is often misplaced since the safety of such water sources is weakly enforced. Therefore, analyses on water use behavior and household water treatment and storage will provide a useful entry in designing DWMO's locality-based scheme.

4.2.2 Implications for Monitoring

The national estimates of the coverage of 'improved water supply' coverage are based on aggregated data from the National Socioeconomic Survey (SUSENAS), a wide-ranging demographic survey conducted periodically. These survey-based data often do not apply to different local settings. For example, in the latest Mid-term Development Plan, the term 'improved water sources' does not occur to indicate the coverage of improved water sources [25]. Moreover, the emphasis on access tends to ignore mixed water source strategies and misrepresents the real types of access in complex urban settings.

The National Statistical Office has changed the way water supply is classified. Before 2011, households were classified as 'improved' if their main drinking water sources originated from improved sources. Since 2011, households are classified as 'improved' if water sources used for bathing/washing activities originate from improved sources. This shift caused a seemingly increasing trend in coverage of improved water supply (see Figure 7). The Ministry of National Development Planning (BAPPENAS) in the National Report on MDGs Progress also included households using bottled water combined with improved water in their estimate. The number of households with access to improved water was revised in the report from 43% to 55% [40].

Likewise, there is a grey area between piped water and water from vendors; most vendors obtain water from water taps and then carry it to the areas beyond the piped network [4]. This issue had been accommodated by SUSENAS; since 2007, the SUSENAS module differentiates households using individual connections of piped water and those who buy piped water from vendors in retail, which caused a significant decrease in access to piped water from 2008 onward (see Figure 7).

This study also provides evidence for the challenges of JMP's approach in monitoring: the current set of indicators does not address the safety and sustainability of water supply sources [41]. Although JMP classifies bottled water as 'improved' if water used for other hygienic purposes originates from improved sources, it is important to differentiate households using bottled water to point out the trend that bottled water use increases, while exclusive access to piped water decreases. The results of this research can be used to improve accountability and to target improvement in terms of access and service quality for both piped water providers and non-piped water system managers.

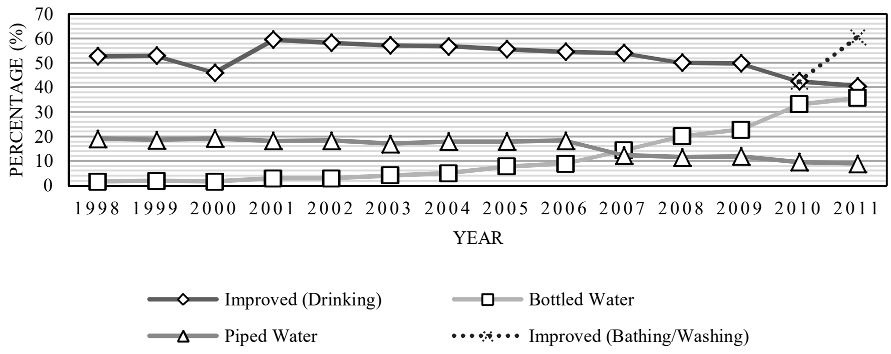

Figure 7 Trends in access to improved sources, bottled water, and piped water in urban Indonesia from 1998 to 2011. The National Statistical Office of Indonesia separates households with access to piped water bought from vendors since 2007. This causes a significant decrease in the level of access to piped water. In 2011, the National Statistical Office reclassified households as having access to 'improved sources' if, within a household, bathing and washing activities are satisfied through one or more improved water sources (data was taken from SUSENAS, the annual socioeconomic survey undertaken by the National Statistical Office, courtesy of Ahmad Komarulzaman).

In the Sustainable Development Goals (SDGs), there is sufficient space for national policy design and adaptation to local settings to avoid a one-size-fits-all solution while continuing to respect international standards. Different national circumstances, capacities, and priorities have to be taken into account [42]. Contextually, the twofold water problems in Indonesian cities as well as the newly developed DWMO strategy require a new perspective on monitoring. Even though a future monitoring framework means taking into account the aspect of water quality, it is expensive to carry out a nation-wide household water quality analysis in Indonesia. At present, the SUSENAS module for drinking water supply focuses on the source of drinking water, the type of access (shared/individual), distance from ground water sources (i.e. borehole, well, or spring) to sanitation facility, and the means of obtaining access (buying/not buying). Moreover, there is no robust monitoring in place to ensure the water safety aspect. The various strategies adopted by vulnerable households demonstrate that when centralized drinking water supply is inadequate, the responsibility for obtaining access to water and securing the safety of drinking water falls to the consumer by default [43]. To accommodate the service quality aspect of urban water systems, the existing statistical approach can be improved by adding a layer of complexity to the dimensions of access: the particular domestic water mix that represents the multiple access routes to various water sources and their specific uses. This will be especially useful in providing evidence for the DWMO policy and for designing effective interventions in addressing Indonesian urban water problems.

4.3 Survey Limitation

One limitation of this study was the random walk and quota sampling strategies used for the slum household survey that may have caused biased household samples, as respondents who were more likely to be available and eager to participate were selected.

5 Conclusion

Where public-provided water is scarce, informal practices thrive; these are complex in nature and are often unaccounted for in the formal monitoring and measuring of sector performance. The sustained use of mixed water sources is a noted example. Should households that have access to both a piped connection and water from vendors, yet rely heavily on the latter due to interrupted supply of the piped service, be considered as 'improved' or 'unimproved'? How can performance reports capture these mixed water sources strategies? This study may contribute to the literature by further acknowledging local complexities on the characteristics of water supply service. The results also have a significant implication for monitoring, mainly since commercial water has a significant increased popularity among households.

Although the JMP classifies households using bottled water as improved if the source for cooking and personal hygiene is improved, the high use of bottled water among improved water users should not be neglected since it suggests a low trust in public-provided water. The reluctance of households to connect to piped water also calls for a major improvement of the accountability of the municipal water supplier in improving its service quality. Innovative approaches of measuring water supply performance are needed to ensure that the service reaches those who need it most. This will be particularly noteworthy when developing water service for vulnerable populations in urban areas within the framework of the post-2015 water agenda. Finally, qualitative studies on households' choices of water sources are needed to better understand differentiated access to water in developing countries.

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