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Estimating the Scope of Household Water Treatment in Low- and Medium-Income Countries

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Abstract. For populations without reliable access to safe drinking water, household water treatment (HWT) provides a means of improving water quality and preventing disease. We extracted data on reported HWT practices from 67 national surveys and reports on the scope of HWT. An estimated 33.0% of the households (1.1 billion people) in these countries report treating their drinking water at home. The practice is widespread in the Western Pacific (66.8%) and Southeast Asia (45.4%) regions, and it is less common in the Eastern Mediterranean (13.6%) and Africa (18.2%). Boiling is the most dominant method with 21.0% of the study households (598 million people) using the method. Despite being at higher risk of waterborne disease because of lower coverage of improved water sources, African and rural households are less likely to practice HWT or use microbiologically adequate methods. Validation of the household surveys and further analysis of these data could help optimize HWT practices.

INTRODUCTION

Unsafe drinking water, along with poor sanitation and hygiene, accounts for nearly 10% of the total burden of disease worldwide.[1] This includes an estimated 4 billion cases of diarrhea disease annually, causing 1.8 million deaths, mostly among children under 5 years of age.[1] By affecting normal consumption of foods and reducing the adsorption of nutrients, diarrheal diseases are also an important cause of malnutrition, which can lead to impaired cognitive development and physical growth,[2] reduced resistance to infection,[3] and potentially, long-term gastrointestinal disorders.[4] Contaminated water is also an important contributor to other potentially waterborn diseases, including hepatitis A and E, cholera, typhoid, and poliomyelitis.

Despite repeated commitments at the highest international levels over the past generation to provide safe drinking water for all, substantial portions of the worldwide population still want for water security. An estimated 884 million people lack access to improved water supplies, drawing their drinking water from lakes and rivers, unprotected wells and springs, and other sources that are often highly contaminated with waterborn pathogens.[5] Most of these people reside in rural settings where piped and other improved water supplies have failed to reach them, despite progress elsewhere toward the Millennium Development Goal (MDG) water target of halving the portion of the population without sustainable access to safe drinking water by 2015. Hundreds of millions more rely on "improved" water sources that are nevertheless subject to frequent and extensive microbial contamination.[6,7] Even tap water supplied to urban dwellers in major cities throughout the developing world is often of uncertain microbiological quality because of inadequate treatment or is subject to seasonal or other periodic incursions of microbial contaminants because of failures in the distribution systems.[8–10]

For those who have access to sufficient quantities of water but whose water is of poor or uncertain microbiological quality, an alternative is to treat their water at home. Treating water at the household level or other point of use also reduces the risk of waterborn disease arising from recontamination during collection, transport, and use in the home, a well-known cause of water-quality degradation.[11] Evidence has shown that treating water at the household level is effective in improving the microbiological quality of drinking water[9] and in preventing diarrheal disease.[12,13] Household water treatment (HWT) does not improve access to water supplies (except by rendering previously unusable supplies safe) or increase the quantity of water used in the home, both of which are necessary for optimal health, domestic hygiene, economic benefits, and other benefits. Nevertheless, HWT has been shown to be one of the most cost-effective interventions for advancing the MDGs.[14,15] The World Health Organization (WHO) now endorses effective HWT as a means of achieving the health gains associated with safe drinking water in those not yet served by reliable piped-in water.[16,17]

Long before these recent efforts, however, householders began using a variety of methods for treating their water before drinking it. Some of these, such as boiling, have been heavily promoted by governments, health-care providers and others, and they are among the most effective microbiologically. Others, such as straining water through a cloth or allowing it to stand and settle, have little microbiological efficacy except in special cases and are mainly practiced to improve aesthetics. Identifying the populations that do and do not treat their water using microbiologically effective methods may help governments, funders, and program implementers to target effective drinking-water interventions, provide piped or other improved water supplies, and, where necessary and appropriate, provide information on HWT methods.

Until recently, there was no systematically collected data on the prevalence of HWT practices. Although some observational and intervention studies have reported on HWT practices, these were limited and sporadic studies of particular communities or regions and do not purport to be nationally representative. Moreover, these studies use their own definitions of HWT practices and methods of data collection, so that aggregation of data across studies is not possible.

Commencing in 2005, however, the WHO/United Nations Childrens Fund (UNICEF) Joint Monitoring Program (JMP), which monitors the water and sanitation sectors and assesses progress toward the MDG water and sanitation targets, began collecting data on HWT practices. Recognizing the potential contribution of HWT in improving water quality at the point of use, the JMP recommended the addition of two questions to national household-level surveys: whether or not respondents treat their water at home before drinking it, and if so, how do they treat it.[18] National governments, statistical offices, and others implementing the survey make their own decisions on

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whether or not to include the recommended questions; they may also choose to modify the questions and responses to reflect local contexts. Beginning in 2007, however, an increasing number of JMP national surveys became available that contained data on HWT practices.

We undertook this study to estimate the overall scope of HWT among those countries for which JMP data on the practice are now available. We extracted the relevant data from the national surveys of 67 countries that participated in the JMP that included questions on HWT use. We then aggregated the data and performed selected descriptive analyses. Results are shown by percentage of households and estimated populations. Results are also broken down by type of HWT method and grouped by "adequate" and "inadequate" methods based on JMP classifications. To determine the use of adequate HWT in those populations that could most benefit from it, adequate HWT use is also presented by access to improved water sources and by wealth quintile.

METHODS

HWT data sources. We extracted data from major national survey programs contributing to the JMP, including the UNICEF-supported Multiple Indicator Cluster Surveys (MICS), the United States Agency for International Development (USAID)-supported Demographic and Health Survey (DHS), the WHO World Health Survey (WHS), and the World Bank's Living Standards Measurement Study (LSMS). DHSs are nationally representative household surveys with sample sizes ranging from 5,000 to 30,000 households depending on the size of the country. These surveys are conducted in more than 70 countries and are repeated every 5 years; 52 DHSs were planned for the 2005–2009 period. MICSs are a nationally representative household survey program with sample sizes ranging from 2,500 to 60,000 households; 49 surveys were planned for the third round of MICSs, which incorporated the HWT questions. The WHSs are nationally representative household surveys with a target sample size of 5,000 households, and these surveys have been conducted in more than 70 countries. The LSMS surveys are much smaller in size with sample size generally in the range of 600–3,200 households per country. The majority of variables gathered in these surveys are collected through a questionnaire and depend on accurate recall by household respondents. Further details about the sampling design, survey management, and quality control are provided in the individual survey reports.[19–21]

HWT practices. Data on HWT practices were derived from two core questions that the JMP recommended be added to surveys commencing in 2005: (i) do you treat your water in any way to make it safer to drink, and, if the response is affirmative, (ii) what do you usually do to the water to make it safer to drink.[18] This set of questions intends to gather information on HWT use at the household level. Whereas the first question asks for a yes, no, or do not know response, the second question identifies several possible options, including boil, add bleach/chlorine, strain through a cloth, use a water filter (ceramic, sand, composite, etc.), use solar disinfection, let it stand and settle, other (specify), and do not know. Respondents could report more than one type of treatment (i.e., filtering and adding chlorine). Because an objective of the questions was to provide an indication of quality of drinking water in the home, the responses were then characterized as "adequate treatment" if the method has been shown to be microbiologically effective (boil, bleach, filter, or solar disinfection) or "inadequate" if not (strain or settle), according to the JMP guidelines.[18] Alternative HWT methods not included in the JMP guidelines were categorized as either adequate or inadequate based on the literature (see the footnote to Table 2 for further details). The option "other HWT" was automatically classified as inadequate, because only the above-mentioned four methods are currently classified as adequate.

Estimating percentages and populations. JMP surveys are designed to be representative of the country as a whole. Accordingly, they can be used to estimate the prevalence of HWT for the country and can be combined with population estimates to estimate the number of people practicing HWT. We used Stata/SE version 10 (Stata Corp., College Station, TX) to calculate the proportion of households reporting the use of HWT. JMP surveys are characterized by complex, non-random sample designs, and most surveys are stratified, clustered, and two-stage surveys. Furthermore, in most cases, samples are selected with unequal probability to expand the number of cases for certain areas or subgroups for which statistics are needed. Weights were used throughout the analysis to restore the representativeness of the sample, and the complex design was taken into account by using the Stata *svyset* and *svy* commands. Because HWT practices may vary over urban and rural settings and aggregated figures might mask this discrepancy, this report provides figures disaggregated on urban and rural areas. Classification of HWT use by water source ("improved" versus "unimproved") was based on the definitions ascribed to such terms by the JMP[18] or the applicable survey. Classification of HWT use by household wealth quintile was based on the definitions used by individual surveys. For those surveys with publicly available datasets, estimates were computed directly, whereas for those surveys with only reports available, only the data available in these reports are presented. To determine the population practicing HWT, we used the estimated proportion of households reporting the use of HWT as a proxy for the percentage of people reporting HWT. We then used the most recent United Nations population estimates (2006 revision) for each country to calculate the population represented by such percentages. This reflects the upper bound of the estimate, because it ascribes the HWT status of the respondent to all members of the household, an assumption challenged by other research noted below.

RESULTS

Survey data. Overall, 70 surveys representing 67 countries were obtained for analysis. From the 49 country surveys compromising the third round of MICSs, 40 had publicly available final reports as of July 2009, two had published the preliminary reports, which did not include estimates for HWT use, one had restricted access, and six surveys were still ongoing. For those surveys with available final reports, 37 had publicly available databases. For the 52 DHSs planned since the HWT core questions were added in 2005, 33 surveys had been completed, and the databases were available. Of these, 26 contained HWT data. DHSs and MICSs before 2005 were also reviewed, and this added two other countries, the Philippines (DHS 1998 and DHS 2003) and the Dominican Republic

(DHS 2002). Of the 33 countries available with LSMS surveys, only the most recent surveys were reviewed for each country. Of these, five countries included data on HWT use. None of the WHSs reviewed included data on HWT use.

The 67 countries for which HWT data were available represent 41% of all world economies and 46.5% of the 144 economies classified as low- and medium-income for 2009 by the World Bank in 2008. Of these, 22 are from Africa, 13 from Latin America and the Caribbean, 7 from the Eastern Mediterranean, 14 from Central and Eastern Europe, 6 from Southeast Asia, and 5 from the Western Pacific (Table 1). Three countries (Egypt, the Dominican Republic, and the Philippines) included data for two separate time points.

Survey dates ranged from 1996 to 2007, and only nine surveys dated from before 2005. The average household response rate was 96.6%, and the range was 85.1% (Jamaica MIC3S) to 100% (Viet Nam MIC3S). The missing data for HWT use was minimal with an average of 0.03% for all surveys (range = 0.00–0.09%).

In 50 of 70 surveys (71%), the JMP core questions on HWT were incorporated verbatim with no modifications. In five surveys (7.1%), the standard JMP question was used, but this was preceded by the following statement: "Do you do anything to make water cleaner before drinking it?" In two surveys, the words "safer to drink" were replaced by "cleaner to drink." In one case, the word "potable" was used instead of "safer," and in another case, "safer to drink" was replaced by "is not dangerous to drink." In 11 cases (15.7%), a question different from the JMP question was asked. These variations included: "How do you treat your drinking water?"; "Do you boil or filter your water?"; and "The water you drink is: boiled, filtered, mineral, other." Forty-seven of seventy surveys (67%) included the standard JMP answer categorization; in the remaining cases, it was only possible to report on those methods included in the survey. Thus, it is likely that HWT use may be underreported in these cases.

Prevalence of reported HWT use. Table 2 shows the percentage of the households reporting HWT use by country for each of the 67 countries for which data are available. Countries are grouped by region, and combined percentages for each area are also shown. Overall, an estimated 33.0% of households in these countries reported treating their water to make it safer to drink. The percentage was 36.6% for urban dwellers and 30.1% for rural households.

The data show substantial differences in the prevalence of HWT by country and geographical region. Although HWT is reportedly practiced by more than 90% of households in Indonesia, Mongolia, Uzbekistan, and Viet Nam, the prevalence is less than 10% in Benin, Burundi, Côte d'Ivoire, Djibouti, Ethiopia, Ghana, Sierra Leone, Egypt, Syrian Arab Republic, Yemen, Armenia, Bosnia and Herzegovina, Georgia, Montenegro, Serbia, and Bangladesh. The practice is most common among countries falling within the Western Pacific WHO region (66.8%) and least common in the Eastern Mediterranean (13.6%) and African regions (18.2%). However, large variations were also observed within geographical regions.

TABLE 1
Countries included in the study by WHO region

WHO region	Countries sampled	Total number of countries	Percentage of countries sampled
Africa	22	46	48
Latin America and the Caribbean	13	35	37
Eastern Mediterranean	7	22	32
Central and Eastern Europe	14	25	56
Southeast Asia	6	10	60
Western Pacific	5	27	19
Total (%)	67	165	41

For a more detailed explanation of WHO regions, see WHO.[52]

These prevalence levels translate into the population estimates summarized in Table 3. Overall, an estimated 1.1 billion people from these middle- and low-income countries reported treating their water to make it safer to drink. A majority of this total resided in five countries included within the Southeast Asia region (652 million) or five countries included in the Western Pacific Region (134 million). This reflects both the comparatively high prevalence of HWT in these regions and their relatively large populations. Once again, Africa has a comparatively small number of people who report treating their water before drinking it (50 million from 22 countries).

Type of HWT. Boiling is the predominant method of HWT with 21.0% of households overall reporting the practice. Boiling is most prevalent in the Western Pacific region (58.7%) and least prevalent in the Eastern Mediterranean (4.0%) and African (4.5%) regions. Boiling is almost universal in Indonesia (90.6%), Mongolia (95.2%), Uzbekistan (98.5%), and Viet Nam (91.0%), and it is widely practiced in Tajikistan (80.3%), Timor-Lester (73.4%), Kazakhstan (67.6%), Azerbaijan (69.5%), and Ecuador (61.4%). Although boiling is relatively rare in Africa (4.5%), there were African countries reporting significantly higher rates, including Uganda (39.8%) and Zambia (15.2%).

Other "adequate" HWT (as defined by the JMP) practices are comparatively less common (Table 2). Overall, the use of chlorine or bleach is reported by 5.6% of households, filtration by 4.3%, and solar disinfection by 0.2%. The use of chlorine or bleach is most prevalent in Latin American and the Caribbean (17.1%), but it is almost non-existent in Central and Eastern Europe (0.9%), Southeast Asia (0.9%), and the Western Pacific (1.7%). The use of filters was comparatively high in Southeast Asia (9.6%) but rare in Africa (0.6%). Filter use was relatively high in the Latin America and Caribbean region (9.1%), especially in Brazil (61.8%) and the Dominican Republic (24.9%).

Householders are as likely to use "inadequate" HWT methods (as defined by the JMP) as they are to use "adequate" alternatives to boiling. Overall, 4.1% of households report straining water through a cloth, whereas 5.1% of households report letting the water settles before consumption. By geographical region, straining is most prevalent in Africa (7.3%) and Southeast Asia (6.9%) followed by the Western Pacific (5.0%); straining is especially high in Guinea-Bissau (70.9%) and Mali (24.0%). In Central and Eastern Europe, householders are more likely to let the water to stand and settle (10.9%) rather than strain it (0.6%).

Urban–rural differences in HWT practices. Overall, the use of HWT is more prevalent in urban (36.6%) than in rural settings (30.1%) (Table 2). Urban and rural differences in use seem to differ by treatment type. Boiling showed a clear pro-urban profile with an overall difference of 4.9% between urban and rural settings. In all WHO regions, boiling was, on average, more common in urban areas. There were, however, exceptions to this trend, such as in Guatemala (47% rural versus 38% urban; P value < 0.01) and Laos (74% for rural versus 47% for urban; P value < 0.001).

TABLE 2
Percentage of households reporting the use of different HWT by country and WHO region

WHO region, country, and year of survey	Percentage treating water			Adequate												Inadequate							Total Adequate			Total Inadequate			IO
				Boil			Bleach			Filter			Solar			Strain			Stand			O								
	T	U	R	T	U	R	T	U	R	T	U	R	T	U	R	T	U	R	T	U	R	T	T	U	R	T	U	R	T
Africa	18.2	21.0	17.0	4.5	7.0	3.6	6.0	8.8	4.3	0.6	0.7	0.5	0.0	0.0	0.0	7.3	5.2	8.6	1.3	1.1	1.5	0.5	10.6	15.6	8.0	8.2	6.2	9.6	8.2
Algeria 2006*	17.2	18.2	16.0	1.2	1.7	0.6	15.0	15.5	14.2	0.9	1.0	0.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.6	16.4	17.5	15.1	0.6†	0.5†	0.7†	ND
Benin 2006	5.7	4.0	5.8	0.2	0.3	0.2	2.9	2.5	3.1	0.2	0.2	0.2	ND	ND	ND	0.8	0.4	1.0	ND	ND	ND	1.6	3.3	3.0	3.5	2.4	1.0	3.3	2.4
Burkina Faso* 2006	14.1	9.4	15.9	0.2	0.1	0.2	1.1	1.3	1.0	1.8	1.8	1.8	0.0	0.0	0.0	10.3	6.3	11.9	0.8	0.3	1.0	0.1	3.0	3.3	2.9	11.2	6.6	12.9	11.0
Burundi 2005	4.0	5.2	4.0	1.6	3.0	1.6	0.0	0.0	0.0	0.1	0.0	0.8	0.0	0.0	0.0	0.1	0.2	0.1	2.3	1.6	2.4	1.0	1.7	3.0	1.6	2.5	2.0	2.5	2.3
Cameroon 2006	11.0	15.1	6.9	1.7	1.7	1.7	3.5	3.9	3.0	1.5	2.8	0.1	0.1	0.0	0.1	3.6	6.0	1.2	1.4	1.5	1.3	0.1	6.4	8.1	4.7	5.0	7.5	2.5	4.6
Cote d'Ivoire 2006	9.4	12.3	7.1	0.5	0.4	0.6	5.0	7.0	3.5	0.6	0.9	0.4	0.1	0.1	0.1	1.3	1.6	1.0	2.4	3.6	1.5	0.3	6.0	8.0	4.5	3.9	5.2	2.9	3.3
Dijibouti 2006*‡	2.8	2.7	4.6	0.9	0.9	0.1	0.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	2.2	0.6	0.5	3.0	0.1	1.8	1.9	0.1	0.9†	0.7	5.2	ND
Ethiopia 2005	7.3	4.8	7.7	2.4	2.9	2.4	0.2	0.6	0.2	0.3	0.6	0.3	0.0	0.0	0.0	4.6	0.6	5.2	0.2	0.1	0.2	0.3	3.0	4.2	2.8	4.9	1.0	5.6	4.2
Gambia 2006	18.4	7.8	28.2	0.3	0.6	0.1	2.6	3.2	2.0	0.3	0.3	0.2	0.0	0.0	0.0	15.7	4.0	26.6	0.2	0.1	0.3	0.0	3.1	3.9	2.3	15.7	4.0	26.6	15.2
Ghana 2006	7.9	7.5	8.2	1.4	1.3	1.5	0.8	1.1	0.6	0.9	1.0	0.8	0.0	0.0	0.1	3.1	2.1	4.0	2.0	2.3	1.9	0.2	3.1	3.4	2.8	5.3	4.5	6.1	4.8
Guinea-Bissau 2006	73.9	71.0	75.6	1.0	1.6	0.7	3.6	7.7	1.1	0.2	0.6	0.0	0.0	0.0	0.0	70.9	67.2	73.1	5.8	2.6	7.7	0.6	4.5	9.1	1.8	72.4	68.0	74.9	69.3
Liberia 2007	16.7	24.4	12.3	0.1	0.3	0.0	15.5	23.4	11.0	0.0	0.1	0.0	0.0	0.1	0.0	0.5	0.4	0.6	0.3	0.3	0.3	0.4	15.6	23.6	11.0	1.2	1.0	1.2	1.0
Malawi 2006	20.0	20.1	20.0	10.2	6.2	10.9	8.8	11.9	8.2	0.2	0.3	0.1	0.0	0.0	0.0	1.5	0.9	1.6	0.7	2.2	0.5	1.3	17.9	17.2	18.0	3.5	3.8	3.4	2.1
Mali 2006	33.7	23.2	38.3	0.2	0.2	0.2	8.7	10.9	7.7	2.5	1.0	3.2	ND	ND	ND	24.0	12.9	28.9	ND	ND	ND	0.2	11.3	12.0	11.0	24.2	12.9	29.1	22.5
Mauritania 2007	29.3	39.1	21.5	0.2	0.3	0.1	19.7	37.3	5.7	0.5	0.3	0.6	0.1	0.1	0.1	9.7	1.9	15.9	0.4	0.3	0.5	0.3	20.3	37.7	6.4	10.2	2.3	16.6	8.8
Namibia 2006	10.4	16.1	5.5	8.1	12.6	4.1	0.2	0.2	0.2	1.3	2.6	0.2	0.0	0.0	0.0	0.2	0.0	0.3	0.4	0.4	0.5	0.3	9.5	15.3	4.5	0.9	0.8	1.0	0.8
Sierra Leone 2005	6.7	11.5	4.7	0.3	0.6	0.1	3.8	8.4	2.0	0.1	0.3	0.0	0.0	0.0	0.0	0.8	1.6	0.5	2.2	2.2	2.2	0.4	4.1	9.2	2.1	3.2	3.9	3.0	2.3
Togo 2006	10.2	9.9	10.3	0.6	0.4	0.7	4.3	5.7	3.4	0.5	0.5	0.5	0.0	0.1	0.0	3.1	1.4	4.3	1.3	1.6	1.0	1.2	5.2	6.5	4.4	5.4	3.8	6.5	4.8
Swaziland 2006	12.1	11.6	12.4	3.0	2.0	3.4	8.2	7.9	8.3	0.5	0.5	0.5	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.2	11.2	10.4	11.6	0.3	0.1	0.5	0.3
Uganda 2006	41.9	70.7	36.6	39.8	68.6	34.4	0.8	1.3	0.7	0.5	1.0	0.4	0.0	0.0	0.0	1.6	1.6	1.6	0.6	0.5	0.6	1.7	40.5	69.5	35.1	3.7	4.8	3.5	1.4
Zambia 2007	34.9	55.1	24.1	15.2	26.5	9.3	25.9	41.6	17.7	0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.7	0.3	0.9	0.1	34.1	54.7	23.2	0.9	0.5	1.1	0.7
Zimbabwe 2005–2006	13.2	22.8	8.8	10.4	21.6	5.2	1.6	1.0	1.8	0.2	0.1	0.2	0.0	0.0	0.0	0.2	0.0	0.3	0.8	0.2	1.0	0.5	12.0	22.4	7.1	1.5	0.5	2.0	1.2
Latin America and the Caribbean	40.0	42.1	36.8	20.6	22.7	17.5	18.7	18.7	19.9	6.9	7.6	4.7	0.2	0.2	0.2	1.3	1.0	1.6	1.8	1.7	1.8	0.8	39.3	41.9	35.6	3.0	2.8	3.0	1.6
Belize 2006	18.7	15.4	22.7	9.4	9.5	9.4	7.5	10.3	5.1	1.6	0.7	2.5	0.1	0.2	0.0	0.2	0.3	0.1	0.3	0.2	0.4	0.7	17.8	14.6	21.5	1.2	1.1	1.3	0.9
Brazil 1996–1997	63.9	68.9	42.9	2.1	2.1	1.8	ND	ND	ND	61.8	66.8	41.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	63.9	68.9	42.9	ND	ND	ND	ND
Cuba 2006	33.0	36.7	23.1	27.8	31.4	18.2	3.3	3.6	2.5	1.2	1.2	1.0	0.0	0.0	0.0	0.5	0.6	0.4	1.4	1.5	1.2	0.3	31.5	35.3	21.2	2.2	2.2	2.2	1.5
Dominican Republic 2007‡§	24.9	31.5	19.5	24.9	31.5	19.5	ND	ND	ND	24.9	31.5	19.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	24.9	31.5	19.5	ND	ND	ND	ND
Dominican Republic 2002‡§	26.3	32.9	20.2	26.3	32.9	20.2	ND	ND	ND	26.3	32.9	20.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	26.3	32.9	20.2	ND	ND	ND	ND
Ecuador 1998‡	70.9	81.9	53.9	61.4	70.8	46.8	7.4	8.0	6.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.1	68.8	78.8	53.2	2.1	3.1	0.6	NA
Guatemala 2000	61.5	58.4	63.9	43.3	37.7	47.5	15.4	15.8	15.1	1.4	2.7	0.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.4	60.0	56.1	63.1	1.5	2.3	0.8	NA
Guyana 2006–2007	53.1	57.6	51.1	10.0	13.8	8.3	41.0	44.6	39.5	1.7	3.2	1.1	ND	ND	ND	0.7	0.5	0.7	6.6	5.9	7.0	0.4	48.6	55.4	45.7	7.7	7.0	8.0	4.3
Haiti 2006‡	32.6	45.6	24.3	2.1	3.4	1.3	30.5	44.6	21.6	0.9	0.6	1.0	0.1	0.2	0.0	0.2	0.3	0.1	0.3	0.4	0.3	2.2	31.5	45.1	22.9	2.8	1.9	3.3	1.0
Honduras 2006	43.2	40.1	46.4	20.9	19.1	22.8	22.0	20.9	23.2	1.3	1.6	1.0	0.5	0.3	0.8	5.7	3.8	7.7	0.2	0.1	0.3	0.4	39.1	37.2	41.0	6.3	4.6	8.0	4.1
Jamaica 2005	49.6	48.6	51.1	33.4	36.1	29.6	25.3	19.4	33.7	2.5	3.7	0.6	0.1	0.1	0.1	0.5	0.3	0.8	1.8	2.0	1.6	0.4	48.9	47.8	50.4	2.6	2.5	2.6	0.6
Nicaragua 2001¶	39.6	38.8	40.4	18.2	23.0	12.5	20.5	15.2	26.6	0.9	0.6	1.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0	44.4	47.0	41.2	0.0	0.0	0.0	ND
Nicaragua 2001**	25.1	19.9	32.7	0.8	0.7	0.8	23.3	18.4	30.5	1.0	0.8	1.4	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0	27.1	23.2	33.0	0.0	0.0	0.0	ND
Panama 2003	17.4	13.3	22.4	6.6	6.3	6.8	9.3	4.7	14.8	1.3	1.8	0.7	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.3	17.1	12.9	22.3	0.3	0.5	0.0	ND
Trinidad y Tobago 2006‡	35.4	ND	ND	21.3	ND	ND	2.8	ND	ND	10.3	ND	ND	ND	ND	ND	0.3	ND	ND	0.7	ND	ND	0.1	33.0	ND	ND	1.1	ND	ND	0.8
Eastern Mediterranean	13.6	18.1	10.4	4.0	6.2	2.8	2.6	5.0	1.4	4.3	5.7	2.4	0.6	0.3	0.9	1.4	1.3	1.5	3.4	2.4	4.4	0.3	9.4	14.6	5.7	4.2	3.3	5.0	3.1
Egypt 2005	5.8	8.3	3.5	0.4	0.6	0.2	0.0	0.0	0.0	3.0	5.5	0.7	0.0	0.0	0.0	0.3	0.4	0.1	2.3	2.0	2.5	0.0	3.4	6.1	0.9	2.6	2.5	2.7	2.4
Egypt 2008	4.9	6.2	3.7	0.4	0.6	0.3	0.0	0.0	0.0	2.9	4.6	1.3	0.0	0.0	0.0	0.3	0.4	0.1	1.5	0.8	2.1	0.0	3.3	5.1	1.6	1.7	1.2	2.2	1.6
Iraq 2006	15.2	14.2	17.2	4.8	5.3	3.7	3.4	2.6	5.2	1.3	1.6	0.8	0.7	0.4	1.4	0.2	0.1	0.5	8.0	6.7	10.9	0.3	9.3	9.1	9.6	8.4	6.9	11.4	5.9
Jordan 2007	21.1	22.3	14.5	3.7	3.5	4.7	0.9	1.0	0.6	16.4	17.8	9.0	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.1	20.8	22.0	14.3	0.1	0.1	0.2	0.1

(*continued*)

Table 2
Continued

WHO region, country, and year of survey	Percentage treating water			Adequate												Inadequate							Total Adequate			Total Inadequate			IO
				Boil			Bleach			Filter			Solar			Strain			Stand			O								
	T	U	R	T	U	R	T	U	R	T	U	R	T	U	R	T	U	R	T	U	R	T	T	U	R	T	U	R	T
Pakistan 2006	10.5	25.0	2.9	6.9	17.9	1.2	0.5	1.3	0.14	1.3	3.4	0.3	0.0	0.0	0.0	2.0	3.7	1.1	0.6	1.2	0.3	0.8	8.5	21.8	1.7	2.6	4.9	1.4	1.9
Somalia 2006	29.4	43.2	21.8	7.7	10.7	6.0	11.3	29.1	1.6	4.4	5.3	3.8	2.3	1.2	2.9	3.9	3.1	4.4	9.6	4.5	12.4	1.0	20.5	39.3	10.1	12.9	7.6	15.8	8.6
Syrian Arab Republic 2006	6.3	6.9	5.5	1.2	1.3	1.1	1.5	1.2	1.8	2.3	3.4	0.9	0.1	0.0	0.1	0.5	0.7	0.4	1.7	1.6	2.0	0.1	4.7	5.4	3.7	2.1	2.0	2.2	1.6
Yemen 2006	7.9	9.0	7.4	3.1	4.4	2.5	0.4	0.0	0.6	1.6	4.1	0.4	ND	ND	ND	2.6	0.7	3.5	0.3	0.0	0.4	0.3	5.0	8.1	3.5	3.1	1.1	4.1	2.9
Central and Eastern Europe	39.4	43.0	33.4	34.6	38.0	29.3	0.9	0.3	1.6	2.8	3.9	0.9	0.3	0.2	0.3	0.6	0.6	0.6	10.9	11.5	9.3	0.7	36.9	40.5	30.9	12.3	12.8	10.8	2.4
Albania 2005	11.2	12.3	10.2	7.1	10.8	4.2	1.6	0.0	2.8	0.4	0.7	2.0	0.0	0.0	0.0	1.4	0.4	2.3	0.4	0.2	0.5	0.5	9.1	11.5	7.2	2.3	1.0	3.3	2.0
Armenia 2005	9.5	10.6	7.4	7.6	8.7	5.4	ND	ND	ND	0.4	0.6	0.1	ND	ND	ND	0.2	0.2	0.2	0.8	0.5	1.3	1.2	8.0	9.2	5.6	2.1	2.0	2.3	1.4
Azerbaijan 2006‡	72.4	81.3	59.6	69.5	78.5	56.5	0.1	0.1	0.2	1.4	1.8	0.7	0.1	0.1	0.1	3.1	4.6	1.0	14.5	17.1	10.8	3.5	69.8	78.9	56.6	20.3	23.1	16.2	2.6
Belarus 2005	62.6	75.3	37.9	52.0	61.8	33.0	0.1	0.2	0.0	13.5	19.1	2.6	ND	ND	ND	0.3	0.4	0.2	18.9	22.5	11.8	0.7	58.6	71.0	34.4	19.6	23.5	12.0	4.1
Bosnia Herzegovina 2006	6.2	4.9	7.1	2.3	3.1	1.8	2.7	0.2	4.3	0.8	1.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.2	0.4	5.7	4.2	6.7	0.7	0.6	0.7	0.5
Georgia 2005	5.7	9.3	2.1	4.3	7.2	1.3	0.1	0.1	0.2	0.1	0.2	0.1	0.0	0.0	0.0	0.2	0.2	0.1	0.7	0.9	0.5	0.5	4.5	7.5	1.5	1.3	2.0	0.7	1.2
Kazakhstan 2006	75.7	79.7	68.5	67.6	69.8	63.7	0.2	0.1	0.3	4.9	7.4	0.4	0.2	0.2	0.1	0.4	0.5	0.2	24.3	27.6	18.2	0.9	69.9	73.1	64.0	25.1	28.9	18.3	5.8
Kyrgyzstan 2006	39.0	40.9	37.5	34.4	36.5	32.8	0.3	0.1	0.4	0.4	0.6	0.3	0.5	1.1	0.1	0.2	0.0	0.4	13.7	13.3	14.0	0.0	34.9	37.3	33.1	13.8	13.4	14.2	4.1
Macedonia 2005	12.3	9.5	16.5	8.6	5.7	13.1	1.7	0.7	3.3	3.2	3.1	3.5	0.3	0.0	0.8	1.3	0.2	3.1	1.5	1.1	2.3	0.1	10.7	8.2	14.7	2.6	1.4	4.6	1.5
Montenegro 2005	9.7	9.6	10.0	3.8	5.0	1.9	0.7	0.1	1.7	0.9	1.4	0.1	0.0	0.0	0.0	0.1	0.0	0.3	0.2	0.2	0.3	0.4	5.7	6.8	3.8	4.3	3.9	6.7	3.8
Serbia 2006	6.1	6.7	5.2	1.7	2.0	1.2	0.7	0.2	1.4	2.0	2.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.5	0.3	1.2	4.5	5.2	3.4	1.7	1.5	1.9	1.4
Tajikistan 2005	82.1	88.3	79.0	80.3	85.6	77.7	0.4	1.1	0.0	0.2	0.7	0.0	1.4	0.8	1.6	0.2	0.7	0.0	13.5	14.4	13.1	0.0	81.2	86.6	78.6	13.7	14.8	13.2	0.8
Ukraine 2005	59.4	74.0	26.7	47.1	59.6	19.4	2.0	0.4	5.7	10.4	14.5	1.1	0.3	0.4	0.2	0.2	0.3	0.1	19.9	24.1	10.4	0.9	55.5	69.2	24.9	20.6	25.1	10.5	3.9
Uzbekistan 2006	99.2	99.1	99.3	98.5	98.2	98.7	0.9	1.1	0.8	0.3	0.8	0.0	0.1	0.1	0.2	0.3	0.4	0.3	43.5	38.0	46.7	0.1	98.6	98.4	98.8	43.6	38.3	46.8	0.6
Southeast Asia	45.4	56.0	42.2	33.1	38.9	31.5	0.9	1.4	0.8	9.6	19.3	6.4	0.8	0.4	1.0	6.9	7.1	6.8	7.5	5.0	9.1	1.3	38.6	50.7	34.8	11.9	10.1	12.9	7.5
Bangladesh 2006‡	7.8	18.9	3.2	4.9	15.0	0.7	0.1	0.2	0.0	1.9	3.5	1.3	ND	ND	ND	1.6	4.0	0.7	0.1	0.0	0.9	1.3	6.5	17.5	2.0	2.8	5.6	1.6	1.2
Timor-Leste 2001	79.7	91.8	76.5	73.4	80.0	71.6	0.1	0.0	0.1	23.2	37.6	19.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.5	76.9	89.5	73.5	3.5	2.5	3.9	ND
India 2005–2006‡	34.4	49.0	27.3	10.4	16.0	7.7	2.3	2.2	2.4	7.8	16.8	3.4	ND	ND	ND	16.6	19.1	15.4	0.6	0.8	0.5	1.7	18.5	31.5	12.2	18.4	21.8	16.8	15.9
Indonesia 2007	92.7	89.2	95.3	90.6	86.4	93.5	1.1	1.0	1.2	4.2	3.9	4.5	0.1	0.1	0.1	ND	ND	ND	23.8	18.8	27.3	1.0	90.9	86.9	93.6	24.8	21.0	27.5	1.9
Nepal 2006	15.4	41.7	10.1	8.7	22.9	5.8	1.2	5.1	0.4	6.3	25.7	2.4	0.2	0.6	0.1	3.1	2.9	3.2	0.2	0.2	0.2	0.1	12.9	39.3	7.5	3.4	3.4	3.4	2.6
Thailand 2005–2006	42.2	45.2	40.8	10.6	13.0	9.4	0.6	0.3	0.8	14.4	28.5	7.9	2.1	0.5	2.8	6.2	2.5	7.9	12.8	5.3	16.7	0.2	26.2	39.5	20.1	18.6	6.7	24.1	16.0
Western Pacific	66.8	68.0	65.8	58.7	60.2	57.7	1.7	0.8	1.9	6.1	8.1	4.7	0.2	0.1	0.2	5.0	4.4	6.1	9.4	6.6	10.2	0.9	62.9	65.5	60.9	8.6	7.2	9.6	4.5
Cambodia 2005‡	66.1	80.4	63.7	60.1	76.0	57.4	0.1	0.1	0.1	2.1	3.3	1.9	0.0	0.0	0.0	0.4	0.7	0.3	11.5	7.4	12.2	1.5	61.4	78.1	58.6	13.1	9.7	13.6	4.7
Mongolia 2005	100.0	100.0	100.0	95.2	95.1	95.2	0.6	0.8	0.3	2.7	4.4	0.4	ND	ND	ND	2.5	0.5	5.1	ND	ND	ND	0.1	97.9	99.4	95.8	2.6	0.7	5.2	2.1
Philippines 2003	42.4	45.1	39.3	27.0	29.7	24.1	1.7	1.6	1.8	5.7	8.4	2.7	ND	ND	ND	11.1	8.6	13.7	ND	ND	ND	0.4	33.2	38.2	27.9	11.4	8.9	14.2	9.1
Philippines 1998	29.4	37.0	22.0	16.4	23.1	9.8	1.7	1.9	1.5	11.2	11.9	10.5	ND	ND	ND	11.1	8.6	13.7	ND	ND	ND	1.4	28.2	35.7	20.9	1.4	1.7	1.2	ND
Viet Nam 2006	94.8	95.0	94.8	91.0	92.4	90.5	5.8	0.3	7.7	13.7	17.5	12.5	0.5	0.2	0.6	2.9	5.1	2.1	9.7	8.9	10.0	1.7	92.7	93.6	92.4	13.8	15.5	13.1	2.0
Lao PDR 2006	68.2	50.6	75.0	62.7	45.1	69.5	0.0	0.1	0.0	1.3	3.3	0.6	0.0	0.0	0.0	2.1	2.9	1.7	7.0	3.5	8.4	0.4	63.9	48.3	70.0	9.3	6.8	10.3	4.2
Total	33.0	36.6	30.1	21.0	23.7	18.8	5.7	6.8	5.2	4.2	5.9	2.7	0.2	0.2	0.3	4.1	3.3	4.8	5.2	4.7	5.0	0.7	28.5	33.2	24.8	8.2	7.2	8.6	5.0

Respondents may report multiple treatment methods, so the sum of treatments may exceed 100%. Regional percentages were estimated using the most recent survey for those countries with more than one survey available. Those countries with no data disaggregated by urban and rural settings were not included in the estimation of the regional average presented in the table. Regional estimates presented here may differ from the main text, because the latter may include all countries when comparing regional prevalence but may not take urban/rural differences into account.

* Only final report available, dataset not released.

† Because of unavailable data, values could not be computed and were estimated by adding individual adequate HWT methods.

‡ Notes on country-specific details. Algeria: Percentages are based on household member population and not households. Azerbaijan: Use of the stone filter was categorized under "other" HWT and classified as an inadequate method. Bangladesh: Alum was classified under "other" HWT, and tribal communities were classified under rural areas. Cambodia: Alum was classified under "other" HWT, and access to improved water was based on access to water from the dry season. Djibouti: Percentages are based on household member population and not households. Dominican Republic (2007): HWT data were not collected for those households using bottled or vendor water, which represented 57% and 10% of household, respectively. Dominican Republic (2002): HWT data were not collected for those households using bottled water, which represented 55% of households. Ecuador: Access to water was not categorized using JMP guidelines, and thus, it was difficult to assess whether or not water sources were improved or not. Haiti: Use of lemon as a method of HWT was classified under "other" HWT, and the use of Pur was classified under bleach and as an adequate method of HWT. India: The use of electric purifiers was classified under filtering and computed as an adequate method of HWT. Philippines: The use of improvised filters was classified as straining and computed as an inadequate method of HWT. Trinidad and Tobago: No area of residence available in the dataset.

§ Surveys only report on either boiling or boiling and filtering, and thus, the estimate for total adequate treatment may be an underestimation.

¶ Residents less than 5 years old.

** Residents greater than 5 years old.

T = total; U = urban; R = rural; ND = no data; O = other; IO = inadequate only.

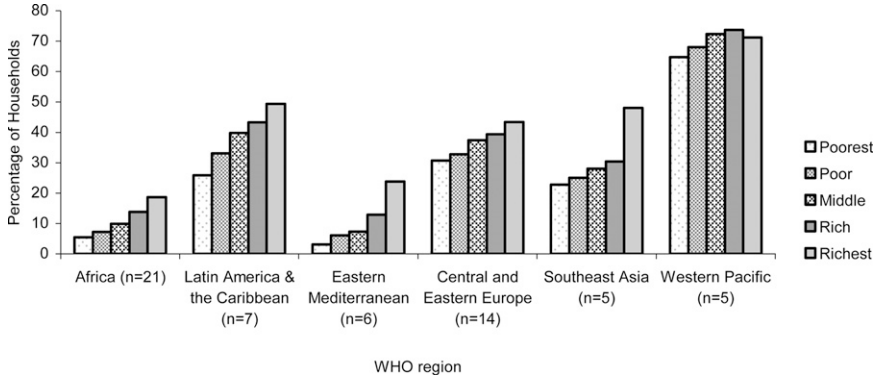

FIGURE 1. Reported adequate HWT use by wealth quintile and WHO region. Average percentage of households reporting the use of an adequate method of HWT (boiling, using a filter, bleach/chlorine or solar disinfection) by household wealth quintile.

In Central and Eastern Europe and in the Western Pacific, the use chlorine or bleach was overall slightly higher in rural than in urban settings. In the remaining regions, the difference in prevalence is generally small with a few exceptions (e.g., Nepal and Somalia). Like boiling, filtering showed a clear pro-urban profile with an overall prevalence in urban areas of 5.9% versus 2.7% in rural areas.

Adequate versus inadequate HWT methods. Overall, 28.5% of households reported using adequate methods of HWT with a higher prevalence in urban (33.2%) than rural areas (24.9%). The use of adequate HWT methods was most common in the Western Pacific (62.9%) followed by Latin America and the Caribbean (39.4%), Southeast Asia (38.6%), and Central and Eastern Europe (36.9%). These data mainly reflect high levels of boiling in these regions and high levels of chlorination or bleaching in Latin America.

Inadequate HWT methods were reported by 8.2% of households, and the practices were slightly more common in rural settings (8.6% versus 7.2%). Overall, in 61.0% of these households, inadequate methods only were used. However, in certain countries and geographical regions, both adequate and inadequate methods were reported to be used in combination (Table 4). This combination of treatment was mainly observed in the Western Pacific, where 8.6% of all households reported using inadequate HWT but only 4.4% were classified as using only inadequate HWT options. In Central and Eastern Europe, 12.3% of all households reported using inadequate methods but only 2.4% were classified as households using inadequate methods solely.

Reported adequate HWT use by access to drinking water. Overall, the use of adequate methods of HWT does not vary considerably between households with access to "improved" (28.6%) versus "unimproved" (26.9%) water sources (Table 5). In Africa, where coverage of improved water sources is lowest,[5] householders were no more likely, on average, to practice adequate HWT based on their water source. The exceptions were Gambia, Ghana, Malawi, Mali, Mauritania, Togo, and Uganda, where adequate HWT was significantly higher among households with unimproved sources. At the same time, however, householders in Liberia, Sierra Leone, and Zambia with improved water sources were more likely to treat their water using adequate methods than those with unimproved water sources. This was also true in both Latin America and the Caribbean and the Eastern Mediterranean. In some cases, the difference was considerable (e.g., Brazil with 70.2% improved versus 39.9% unimproved [P value < 0.001] and Somalia with 34.7% improved versus 14.9% unimproved, [P value < 0.001]). Bangladesh is one of the few examples in which householders relying on unimproved water sources were more likely to treat their water using an adequate method than householders relying on improved (27.3% unimproved versus 6.0% improved; P value < 0.001).

Adequate HWT use by household wealth. Overall, the reported use of "adequate" HWT methods increased by wealth quintile (Table 5 and Figure 1). An overall increase in reported use was observed in all regions. However, there were exceptions to this trend; in Benin, Ghana, Guatemala, Macedonia, and Kyrgyzstan, no significant differences were observed between wealth quintiles. In certain countries, the reported use of adequate HWT methods was largely limited to the richer quintiles. This was especially true in Pakistan, Bangladesh, and Nepal, but it was also the case in Guinea-Bissau, India, Mauritania, Sierra Leone, and Egypt. In a few countries, including Bosnia and Herzegovina, Indonesia, Lao People's Democratic Republic, and Panama, however, the opposite trend was observed with reported use of adequate HWT options decreasing with wealth.

DISCUSSION

With the introduction of questions on HWT practices in nationally representative household surveys, it is now possible to estimate self-reported use of HWT at the national level, independent of the potential bias of focused studies; additionally, these surveys use similar metrics and definitions across countries and regions. Sixty-seven countries were included in this study, representing 46.5% of all low- and middle-income countries. Overall, 33.0% of households or an estimated 1.1 billion people report treating their water to make it safer to drink. However, this figure does not include large populations for which data is not yet available. A substantial portion of the Chinese population is believed to boil or otherwise heat their water before drinking it, especially in colder seasons.[22–24] Other countries with evidence of high rates of boiling that have not yet been reported on in JMP surveys include Chile (population of 16.5 million; 55–57% prevalence[25]) and Peru (population of 27.6 million; 65% prevalence).[26] Thus, it is likely that the actual number of people from low- and middle-income countries who practice some form of HWT may exceed 1.5 billion.

TABLE 3
Estimated population reporting the use of HWT per country and WHO region (in thousands)

	Treat	Adequate*	Boil	Bleach	Filter	Solar	Stand	Strain	Other
Africa	49,575	35,416	20,046	14,941	2,046	54	2,422	12,455	1,745
Algeria	5,736	5,470	400	5,003	300	ND	ND	ND	200
Benin	497	289	22	252	15	ND	ND	69	138
Burkina Faso	2,023	435	24	154	259	0	121	1,482	12
Burundi	330	138	135	0	6	0	191	5	80
Cameroon	1,999	1,161	308	628	264	9	260	659	23
Cote d'Ivoire	1,779	1,139	99	951	114	13	458	239	61
Dijibouti	23	15	7	7	0	0	5	2	1
Ethiopia	5,878	2,418	1,978	190	275	4	123	3,697	250
Gambia	305	51	5	43	4	0	4	260	0
Ghana	1,809	708	321	188	210	9	470	718	48
Guinea-Bissau	1,216	74	17	58	4	1	95	1,167	11
Liberia	598	559	4	555	2	1	10	19	13
Malawi	2,714	2,425	1,390	1,191	21	3	98	200	178
Mali	4,036	1,348	27	1,038	300	ND	ND	2,872	23
Mauritania	891	617	5	600	15	4	11	295	9
Namibia	213	194	165	3	27	0	9	4	6
Sierra Leone	382	237	15	220	6	1	129	46	20
Togo	651	335	37	279	31	2	82	198	76
Swaziland	138	127	34	93	6	0	0	1	3
Uganda	12,531	12,103	11,891	246	158	0	177	479	513
Zambia	4,076	3,987	1,782	3,034	7	8	79	14	10
Zimbabwe	1,750	1,586	1,381	208	24	0	101	29	70
Latin America and the Caribbean	153,118	152,117	24,757	10,409	118,636	52	310	505	768
Belize	53	50	27	21	4	0	1	1	2
Brazil	120,958	120,977	3,908	ND	117,058	ND	ND	ND	ND
Cuba	3,718	3,546	3,133	370	131	3	156	61	39
Dominican Republic†	771	771	771	ND	772	ND	ND	ND	N
Ecuador	9,358	9,078	8,099	978	ND	ND	ND	ND	281
Guatemala	8,013	7,817	5,642	2,006	182	ND	ND	ND	182
Guyana	392	359	74	303	13	ND	49	5	3
Haiti	3,078	2,975	202	2,880	82	8	31	21	209
Honduras	3,009	2,722	1,457	1,536	92	38	15	399	29
Jamaica	1,340	1,318	902	683	66	2	49	14	11
Nicaragua‡	1,387	1,501	43	1,288	56	ND	ND	N	1
Panama	572	563	217	306	43	ND	ND	N	9
Trinidad y Tobago	470	438	283	37	136	ND	9	4	2
Eastern Mediterranean	31,462	23,697	14,613	3,230	6,778	437	5,564	4,443	1,506
Egypt 2008	3,615	2,448	323	3	2,137	5	1,092	188	1
Iraq	4,330	2,637	1,370	979	375	212	2,292	63	80
Jordan	1,207	1,192	210	54	941	ND	ND	ND	7
Pakistan	16,883	13,703	11,152	860	2,163	17	969	3,182	1,267
Somalia	2,482	1,727	649	958	369	192	812	333	80
Syrian Arab Republic	1,224	906	240	282	451	11	336	103	10
Yemen	1,721	1,084	670	94	342	ND	63	573	61
Central and Eastern Europe	87,746	83,573	78,038	1,548	7,452	349	29,515	680	1,164
Albania	354	288	225	50	13	1	11	45	17
Armenia	286	240	229	ND	13	ND	23	6	36
Azerbaijan	6,087	5,863	5,841	11	115	7	1,221	259	293
Belarus	6,101	5,707	5,070	11	1,313	ND	1,836	31	70
Bosnia Herzegovina	245	224	90	107	33	0	11	0	15
Georgia	252	198	189	5	6	0	31	7	21
Kazakhstan	11,588	10,697	10,358	23	749	27	3,714	66	142
Kyrgyzstan	2,050	1,834	1,809	13	23	28	718	11	2
Macedonia	250	218	175	36	66	6	31	27	2
Montenegro	58	34	23	4	6	0	1	1	2
Serbia	596	440	163	68	196	0	43	4	119
Tajikistan	5,451	5,394	5,334	27	15	90	899	16	1
Ukraine	27,655	25,825	21,947	951	4,823	159	9,251	115	402
Uzbekistan	26,773	26,611	26,584	242	82	32	11,723	90	40
Southeast Asia	652,149	451,737	344,354	30,211	113,318	1,512	69,767	198,412	23,902
Bangladesh	12,114	10,158	7,620	120	2,983	ND	113	2,554	2,104
Timor-Leste	888	857	818	1	258	ND	ND	ND	40
India	395,857	212,613	119,552	26,813	89,526	ND	7,139	191,075	19,262
Indonesia	212,248	207,923	207,259	2,556	9,697	157	54,378	ND	2,371
Nepal	4,262	3,557	2,405	323	1,750	47	48	867	30
Thailand	26,780	16,629	6,700	398	9,104	1,308	8,089	3,916	96
Western Pacific	134,170	123,551	116,339	6,519	17,208	408	10,423	12,231	2,052
Cambodia	9,384	8,716	8,530	18	293	1	1,630	54	218
Mongolia	2,605	2,550	2,479	16	70	ND	ND	64	3

(*continued*)

Table 3
Continued

	Treat	Adequate*	Boil	Bleach	Filter	Solar	Stand	Strain	Other
Philippines	36,533	28,674	23,317	1,473	4,923	ND	ND	9,532	355
Viet Nam	81,723	79,930	78,404	5,010	11,845	407	8,390	2,462	1,453
Lao PDR	3,925	3,681	3,609	2	76	0	403	118	22
Total (millions)	1,108	870	598	67	265	3	118	229	31

* According to JMP, this includes boiling, use of a filter, bleach/chlorine, or solar disinfection. Estimates are based on the most recent data for those countries with more than one survey.
† Data were not collected for those households using bottled or vendor water, which represent 57% and 10% of all households, respectively.
‡ Estimated population based on reported use for greater than 5 year olds (estimate only).

Although householders report practicing a variety of HWT methods, boiling dominates. Boiling is characterized by the JMP as an "adequate" method, and few approaches are as effective microbiologically. This is true even in the presence of high levels of turbidity (suspended solids) that often characterize surface sources on which vast amounts of rural and other low-income populations depend, especially during the rainy season. Although boiling has some shortcomings in actual practice and may be more costly and damaging environmentally, it is nevertheless the benchmark against which other HWT methods must be measured.[27–32] The universality of boiling in some countries shows clearly how effective HWT can be embraced on a large scale by vulnerable populations.

Approximately 15% of households that report treating their water simply strain it through a cloth or let it stand and settle, methods that are unlikely to render water microbiologically safe under most circumstances. This suggests that a substantial number of households are committing time and effort to treat their water, although these methods have proved little effectiveness at improving the microbiological quality of water.[9] Because the wording of the question in most cases expressly asks about making water "safer," it seems that these householders are not merely taking this step to improve water aesthetics, which might be the case of those households that report using both adequate and inadequate methods of HWT. Research has shown that many householders judge the quality and safety of their drinking water based on aesthetics (suspended solids, color, odor, and taste),[33,34] and under these criteria, these methods (classified as inadequate by the JMP) may seem to render water "safer" to drink. These results suggest that significant health gains may be possible if these households could be persuaded to use HWT methods that make water microbiologically safer. Accordingly, to achieve substantial uptake and sustained use, it may be necessary to improve and put greater weight on aesthetics and not just simply focus on quality. Even under these circumstances, however, it is unclear to what extent householders can be converted to using adequate HWT methods.

These results also suggest that the practice of effective HWT may not correspond with the risk of waterborne disease. Rural populations, for example, are much less likely to have piped water supplies or other improved water sources; in 2006, rural dwellers represented 84% of the population worldwide using unimproved sources of drinking water.[5] However, in all geographical regions, rural populations are less likely to be treating their water using an adequate method.[5] With only 58% of its population having access to improved water sources, sub-Saharan Africa is one of the regions most likely to rely on unsafe water supplies. Nevertheless, only 10.6% of the population in 22 Africa region countries report practicing adequate HWT. Moreover, use of adequate HWT methods did not differ considerably among those households with improved access to drinking water and those with unimproved access. The use of adequate HWT methods was observed to be particularly low among the poorest households, which are also likely to suffer from higher levels of risk associated with waterborne disease.[35]

This study has certain shortcomings. First, data on HWT are still only available for a limited number of countries. The results presented here should not be used to draw conclusions of the prevalence of HWT in other countries outside this assessment, because the representativeness of this sample is not assured. Second, despite JMP promotion of a standard set of questions for assessing HWT,[18] some of the actual country surveys use variations in the questions or possible responses. This creates challenges in attempting to compare results across countries and may lead to underreporting in certain countries where the full range of HWT methods was not included in the survey exercise. Third, although the JMP household-based surveys may be the most reliable practical means of collecting data on HWT practices, there is a debate on the reliability of these data for public health use.[36,37] JMP surveys are based on questionnaires, and thus, they may be subject to report and recall bias.[36] Several studies have shown that respondents consistently and significantly over-report "good" practices, including handwashing,[38–40] and this is likely to be equally true for HWT. In a recently published evaluation of a 3-year HWT and handwashing intervention, self-reported HWT use was observed to be 3.5–6.5 times higher than use confirmed by the presence of materials necessary to treat water and water that was actually treated at the time of the interview.[41] In a similar study assessing a solar-disinfection intervention, self-reported use was observed to be 1.5–7.7 times higher than confirmed use.[42] However, in these studies,

TABLE 4
Percentage distribution of households according to the mode of HWT use

Region	Number of surveys	No treatment	Only adequate	Only inadequate	Both treatments
Africa	20	80.6	10.1	8.0	0.7
Latin America and the Caribbean	7	62.0	34.3	1.9	1.5
Eastern Mediterranean	7	85.8	9.1	3.2	1.2
Central and Eastern Europe	14	60.4	27.0	2.4	9.9
Southeast Asia	5	61.4	24.9	7.5	6.1
Western Pacific	5	25.7	64.2	4.4	5.6
Total (%)	58	67.7	22.9	5.0	4.0

Not all countries had available datasets or the appropriate format to compute the mode of HWT used.

TABLE 5
Percentage of households reporting the use of adequate HWT methods by access to drinking water sources and household wealth quintiles

Region/country	Source of drinking water			Household wealth quintile			
	Improved	Unimproved	Poorest	Poor	Middle	Rich	Richest
Africa	10.7	11.5	5.5	7.2	9.9	13.8	18.7
Algeria 2006	15.5	22.0	15.5	15.7	16.2	16.3	18.4
Benin 2006	1.7	7.2	3.7	3.7	2.3	3.0	3.8
Burkina Faso 2006	2.7	4.3	1.6	2.4	3.4	3.9	3.8
Burundi 2005	1.4	2.2	0.9	1.3	2.1	1.4	3.0
Cameroon 2006	6.8	5.4	2.5	4.5	7.1	6.5	10.4
Cote d'Ivoire 2006	5.9	6.4	3.7	5.1	8.8	8.8	4.1
Dijibouti 2006	1.9	0.6	ND	ND	ND	ND	ND
Ethiopia 2005	2.5	3.7	1.8	2.3	1.9	4.0	4.9
Gambia 2006	2.4	7.5	1.1	2.8	2.3	4.5	4.3
Ghana 2006	2.5	5.0	4.1	2.8	2.1	2.3	4.5
Guinea-Bissau 2006	6.0	2.3	0.6	2.3	2.0	5.2	12.5
Liberia 2007	21.0	5.5	4.3	10.0	18.5	23.2	23.8
Malawi 2006	15.7	24.3	16.0	15.5	17.8	20.0	20.4
Mali 2006	7.4	16.2	9.8	10.9	9.9	17.1	8.0
Mauritania 2007	14.0	26.9	3.1	6.0	15.0	30.1	46.0
Namibia 2006	9.6	8.5	3.9	4.5	3.3	7.7	24.9
Sierra Leone 2005	8.1	0.7	0.2	0.9	3.5	6.7	10.0
Togo 2006	4.3	6.8	2.9	3.2	4.4	6.4	7.7
Swaziland 2006	10.6	12.6	7.0	9.6	11.4	12.8	13.5
Uganda 2006	36.3	48.9	11.0	22.0	40.9	49.7	77.0
Zambia 2007	46.2	25.6	15.7	19.9	27.5	47.5	62.7
Zimbabwe 2005–2006	12.3	10.9	6.3	6.0	7.4	12.1	27.9
Latin America and the Caribbean	38.1	32.2	25.9	33.1	39.8	43.3	49.4
Belize 2006	17.5	25.4	20.3	20.1	20.1	15.8	13.9
Brazil 1996–1997	70.2	39.7	35.5	50.1	64.1	73.2	82.7
Cuba 2006	32.7	18.9	ND	ND	ND	ND	ND
Dominican Republic 2007	25.5	16.2	16.5	23.5	32.3	42.5	68.1
Ecuador 1998	ND	ND	ND	ND	ND	ND	ND
Guatemala 2000	60.2	59.6	62.3	62.5	58.0	NA	NA
Guyana 2006–2007	49.9	30.6	35.5	49.7	52.7	51.9	50.8
Haiti 2006	36.8	22.7	12.9	19.2	29.9	42.1	52.6
Honduras 2006	39.0	39.5	38.7	41.9	45.4	40.3	29.6
Jamaica 2005	48.9	48.9	ND	ND	ND	ND	ND
Nicaragua under 5s	46.1	33.4	ND	ND	ND	ND	ND
Nicaragua over 5s	26.8	29.8	ND	ND	ND	ND	ND
Panama 2003	16.0	27.5	21.5	22.4	15.1	NA	NA
Trinidad y Tobago 2006	33.2	27.4	21.7	27.4	34.4	37.0	48.2
Eastern Mediterranean	13.0	7.0	3.1	6.1	7.3	12.9	23.8
Egypt 2005	3.4	1.7	0.1	0.3	0.6	2.3	11.4
Egypt 2008	3.4	0.4	0.1	0.6	0.9	2.5	10.5
Iraq 2006	9.3	8.4	ND	ND	ND	ND	ND
Jordan 2007	24.3	12.9	8.3	15.0	19.4	29.3	34.8
Pakistan 2006	8.7	4.9	0.2	0.7	2.0	8.1	32.6
Somalia 2006	34.7	14.9	5.5	13.2	14.1	27.4	45.9
Syrian Arab Republic 2006	4.9	3.1	1.8	4.1	4.1	5.1	7.5
Yemen 2006	5.6	4.2	2.7	3.0	3.4	5.0	11.6
Central and Eastern Europe	36.8	36.0	30.8	32.8	37.4	39.4	43.4
Albania 2005	9.2	4.6	6.7	7.3	8.7	12.7	9.5
Armenia 2005	8.0	9.1	5.7	5.0	8.2	9.0	12.5
Azerbaijan 2006	70.0	68.7	54.8	60.5	66.4	74.1	88.7
Belarus 2005	58.8	19.9	30.0	48.1	66.1	73.9	80.1
Bosnia Herzegovina 2006	5.7	4.0	8.1	7.0	6.1	2.8	4.0
Georgia 2005	4.5	2.1	0.9	1.5	2.6	7.4	10.1
Kazakhstan 2006	69.4	77.7	66.4	64.5	61.9	73.3	78.7
Kyrgyzstan 2006	33.5	47.7	38.6	35.6	33.4	30.4	36.6
Macedonia 2005	10.7	16.7	13.3	9.4	11.8	8.2	11.1
Montenegro 2005	5.7	2.8	2.6	5.0	7.3	6.1	7.5
Serbia 2006	4.4	7.9	2.6	2.9	4.0	4.8	8.0
Tajikistan 2005	81.4	80.9	79.0	77.0	77.8	80.2	89.1
Ukraine 2005	55.3	63.3	22.9	37.2	70.9	70.3	72.8
Uzbekistan 2006	98.6	98.8	99.2	98.6	98.6	98.3	98.5
Southeast Asia	39.4	40.3	22.8	25.0	28.0	30.4	48.1
Bangladesh 2006	6.0	27.3	0.5	1.5	2.4	2.9	26.5
Timor-Leste 2001	81.9	72.2	ND	ND	ND	ND	ND
India 2005–2006	18.0	22.0	4.4	7.7	12.3	22.1	46.0
Indonesia 2007	90.1	92.4	92.6	94.9	94.6	89.7	81.6
Nepal 2006	14.0	7.9	1.2	2.6	4.6	8.6	42.8
Thailand 2005–2006	26.6	19.8	15.2	18.5	26.0	28.6	43.4

(*continued*)

Table 5
Continued

Region/country	Source of drinking water			Household wealth quintile			
	Improved	Unimproved	Poorest	Poor	Middle	Rich	Richest
Western Pacific	64.1	61.1	64.7	68.0	72.4	73.7	71.3
Cambodia 2005	62.1	61.6	39.8	46.8	60.9	74.7	87.1
Mongolia 2005	98.5	96.3	94.3	97.2	98.5	99.3	99.7
Philippines 2003	35.0	28.6	27.1	29.5	34.0	36.4	39.6
Philippines 1998	28.6	26.0	ND	ND	ND	ND	ND
Viet Nam 2006	92.6	93.7	88.2	92.5	94.5	93.1	93.6
Lao People's Democratic Republic	67.5	60.3	74.2	74.0	74.0	65.2	36.3
Total	28.6	26.9	20.4	23.2	26.8	30.0	35.9

For a more detailed explanation of drinking-water sources classification, see reference 18, and for an explanation of the household wealth index, see references 19–21.

data on HWT use were collected at a single point in time, a method that research has suggested may fail to capture the actually practices and may lead to misclassification compared with longitudinal methods.[38,43] There is a need to validate the JMP survey results to ensure that they actually reflect household practices. Even if households do not over-report the use of HWT, however, research from other HWT studies have shown that people who report treating their water often fail to do so consistently or correctly,[26,30,44,45] often practicing HWT only when they have a perceived need. As the health benefits corresponding to improved water quality rely on compliance,[12] following the practice only when householders regard themselves at risk (such as during outbreaks or rainy seasons) or have the time or resources to treat their water will not result in optimal health gains. Fourth, the JMP indicators for HWT have certain shortcomings in predicting the efficacy of the practice. For example, after boiling, "use a water filter" was the most common means of reported water treatment. However, because this response includes filters using virtually any type of filter media, it is likely to include a large range of microbiological efficacy. Fifth, the characterization of certain types of methods as "adequate" has not been validated in the field. As noted above, even the microbiological performance of boiling has been shown to be suboptimal when actually practiced by a vulnerable population. This is also true of chlorination, because of poor-quality chlorine supplies, inadequate or inconsistent dosing, and recontamination when water lacks a sufficient residual level of disinfectant and is not accompanied by safe storage.[30,44,46–48] Solar disinfection and filtration are also subject to improper performance, inconsistent use, and recontamination.[49,50] Sixth, results from the more extensive questions used in the Cuba 2006 MIC3, the Dominican Republic 2007 DHS, and the Nicaragua 2002 DHS suggest that treated water is not consumed uniformly by all members of the family. In these three examples, it was observed that, in 67–74% of cases, treated water was reported to be consumed by all family members, whereas in the remaining cases, it was only directed to children or part of the family. These examples are only available for Latin American countries, and thus, it is hard to judge how they may apply in other countries. We do recognize that, by assuming that all household members consume the treated water, our population estimates may partly overestimate the number of people consuming treated water at the home, and therefore, these numbers should be considered as upper-bound estimates only. Finally, even in the case where treated water was consumed by all family members, it remains unclear if this was the sole source of drinking water or if treated water represented a portion of all water consumed. Moser and others[42] reported that those in households reporting treated water still drank a considerable amount of untreated water with an average of 18.9%, although considerable variation was observed between sites (6.3–61.7%). Likewise, McLennan[51] reported that even among those who reported purifying water, only 42% of caretakers reported that it was rare for the index child to drink untreated water. Thus, if raw water is drunk in addition to treated water in households classified as HWT users, it is unclear what the risk of waterborne diseases would be in these households. There is a need for greater validation of the HWT portion of the JMP surveys.

Notwithstanding these limitations, these results do provide the most complete picture to date on the scope of self-reported HWT practices worldwide. If the survey results are shown to validly reflect household practices, they are also useful as a base for future research. As noted, it will be useful to draw on other data from JMP surveys to develop a profile for people who do not practice effective HWT to better target interventions. Data on HWT practices can also be compared with morbidity and mortality data from diarrhea and other diseases to further explore the health impact of the intervention. We are currently combining these results with cost data on different cooking fuels to estimate the global expenditure for boiling and the potential cost savings from alternative HWT. We are also using these results to estimate the greenhouse gases associated with boiling and the possible reduction in carbon footprint that may be achieved by converting boilers to more efficient HWT approaches. Further analysis of these data will help target and improve coverage of effective and sustainable HWT methods among populations at greatest risk of waterborne disease.

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