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Assessing the Microbial Quality of Improved Drinking Water Sources: Results from the Dominican Republic

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Abstract. Millennium Development Goal Target 7c (to halve between 1990 and 2015 the proportion of the global population without sustainable access to safe drinking water), was celebrated as achieved in 2012. However, new studies show that we may be prematurely celebrating. Access to safe drinking water may be overestimated if microbial water quality is considered. The objective of this study was to examine the relationship between microbial drinking water quality and drinking water source in the Puerto Plata region of the Dominican Republic. This study analyzed microbial drinking water quality data from 409 households in 33 communities. Results showed that 47% of improved drinking water sources were of high to very-high risk water quality, and therefore unsafe for drinking. This study provides evidence that the current estimate of safe water access may be overly optimistic, and microbial water quality data are needed to reliably assess the safety of drinking water.

INTRODUCTION

According to the World Health Organization/United Nations Children's Fund Joint Monitoring Program (JMP), as of 2011, 82% of the total population of the Dominican Republic had access to an improved drinking water source.¹ The JMP defines an improved drinking water source as a piped water connection located inside the user's dwelling, plot or yard, public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs and rainwater collection.² This definition, although identifying improved sources, fails to account for microbial water quality, and therefore over-estimates the population with access to safe drinking water.³ At the time this definition was created, there were no simple, affordable ways to regularly and routinely measure the microbial quality of water to quantify its safety within the survey programs being used. It is only more recently that affordable and accessible microbial water quality analysis methods have become available to measure water safety. These new methods should now be implemented to identify water as being truly improved and safe to drink. When defining an improved water source, taking into consideration water quality and sanitary risk, global estimates of a recent study assess that one billion persons believed to be using an improved source are in fact not drinking microbially safe water.⁴

The Dominican Republic has been struggling to make country-level progress in having all achieve access to safe drinking water. Over the past 20 years, the percentage of the population in the Dominican Republic with access to an improved water source has decreased slightly from 89% in 1990 to 82% in 2011.¹ Globally, the Dominican Republic lags just behind the global estimate of 89% of the world population that has access to an improved drinking water source.³ However, taking into consideration water quality would very likely further reduce these values.

This study examines the microbial water quality and water source relationship in the Puerto Plata region of the Dominican Republic through assessing *Escherichia coli* concentrations in household drinking water. By evaluating the microbial quality of the water, the true classification of water sources as being safe can be more accurately assessed by taking into consideration quality when classifying a water source as improved versus unimproved.

MATERIALS AND METHODS

Study design and ethics. The study was conducted in the Puerto Plata region by taking water samples from all households within communities that satisfied the following inclusion criteria: storage of water in the home; at least one child less than five years of age in the household; and willingness to participate. Households were not included if they satisfied any of the following exclusion criteria: unwillingness to participate; no child less than five years of age in the household; exclusive use of bottled water for drinking. In this study, 409 samples from 33 communities were included during the months of May–August 2012. Communities were chosen based upon epidemiologic information from the Department of Public Health in Puerto Plata.

Through the course of the study, 409 samples were obtained. Samples were obtained from the following improved water sources: rainwater (76), piped water (102), protected wells (31), protected spring (1). Samples were also obtained from the following unimproved sources: bottled water (110), unprotected wells (28), unprotected spring (2), rivers (33), and trucked (26). All samples were used for microbial testing of total coliforms and *E. coli* during May–August 2012.

Surveys were also conducted to identify the knowledge, attitudes, and practices of the households regarding water, sanitation, and hygiene, and to determine the prevalence of diarrhea in the household. The data to address the parameters and variables described above were collected by using household surveys that resemble demographic and health surveys. Households were invited to participate in the surveys and informed consent was obtained for their participation. University of North Carolina and Dominican Republic authorities required ethical review by an Institutional

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TABLE 1
World Health Organization water quality risk categories of improved and unimproved sources*

Primary drinking water source	Water quality by source: <i>Escherichia coli</i> MPN/100 mL (as average drinking water source in the household†)				No. (%) HHs using water source
	Low risk, < 1, no. (%)	Intermediate risk, 1–10, no. (%)	High risk, 10.1–100, no. (%)	Very high risk, > 100, no. (%)	
Improved	2 (1)	108 (51)	55 (26)	45 (22)	210 (51)
Unimproved	2 (1)	102 (51)	40 (20)	55 (28)	199 (49)

*MPN = most probable number; HHs = households.

†For households with multiple primary sources of drinking water, an average of the samples from all sources was taken.

Review Board application (#12-1135) addressing the human ethics considerations of this survey program. An Institutional Review Board application was therefore prepared, submitted, and approved by University of North Carolina and Dominican Republic authorities.

Sampling and interviews. Surveys were carried out by five local Dominican women who were recruited and trained as survey staff. They were all ethnically similar to the study population and spoke the local language (Spanish). The survey questionnaire was developed based on previously used questionnaires from prior studies that were tailored to the needs and goals of this project.

Household water quality was assessed by analyzing concentrations of total coliforms and *E. coli* bacteria in raw and treated or stored water. Water was collected in 500-mL Whirl-Pak bags and analyzed by using Colilert medium in Quanti-Tray 2,000-well trays (IDEXX Laboratories, Westbrook, ME). Water sample volumes of 100 mL were mixed with the Colilert reagent, sealed in the Quanti-Trays, and incubated for 24 hours at 35°C to determine the concentration of total coliforms and *E. coli* present in the water. Only *E. coli* data are included in this report because this is the fecal indicator bacterium recommended by the World Health Organization to determine the microbial safety of water.⁵

RESULTS

The WHO water quality guidelines stipulate that one is at low risk when the *E. coli* most probable number (MPN)/100 mL is < 1, intermediate risk when *E. coli* MPN/100 mL is 1–10/100 mL, at high risk when the *E. coli* MPN is > 10–100/100 mL, and at very high risk when the *E. coli* MPN is > 100/100 mL.⁶ As seen in Table 1, just under half of the improved sources in our study had *E. coli* concentrations > 10, deeming them of at least high risk to consume. Fifty-one percent of samples taken from improved sources were of

intermediate risk, 26% were of high risk, and 22% were of very high risk.

Over half of the unimproved sources in our study qualified as intermediate risk, with *E. coli* MPN/100 mL between 1 and 10. However, 20% of samples taken from unimproved sources were high risk, and 28% were very high risk. Of the 210 samples taken from improved sources, 100 (47%) were of high to very high risk, according to their microbial quality measured as *E. coli* MPN/100 mL. Of the 199 samples taken from unimproved sources, 95 (47%) were of high to very high risk based on microbial quality for *E. coli*. When comparing unimproved and improved sources for their categorical concentration of *E. coli* through a chi-square test for trend ($P = 0.35$), there was no statistically significant difference.

Considering each water source, as displayed in Table 2, we found that households reporting the use of river water had the greatest percentage of samples with either high or very high risk water (82%). Although households obtaining their drinking water from rivers only comprised 8% of the total households, it is clear that this water is highly contaminated. Households with bottled water as the primary drinking water source made up the largest proportion (27%). This water was mostly of intermediate risk, with 63% of households having drinking water between 1 and 10 *E. coli* MPN/100 mL, 25% with high-risk water, and 10% with very high risk water. Piped water, the second largest proportion of household water source (25%), was more contaminated than bottled water, with 20% of household drinking waters having > 100 *E. coli* MPN/100 mL, 25% with high risk water having > 10–100 *E. coli* MPN/100 mL, and 54% with intermediate risk water having 1–10 *E. coli* MPN/100 mL.

DISCUSSION

This study of the microbial quality of water in Puerto Plata, Dominican Republic reinforces the need to include

TABLE 2
Escherichia coli MPN/100 mL as average drinking water source in the household, Dominican Republic*

Source category	Source type	Water quality by source				No. (%) HHs using water source
		Low risk, < 1, no. (%)	Intermediate risk, 1–10, no. (%)	High risk, > 10–100, no. (%)	Very high risk, > 100, no. (%)	
Improved	Rain	1 (1)	45 (60)	20 (26)	10 (13)	76 (19)
	Piped	1 (1)	56 (54)	25 (25)	21 (20)	102 (25)
	Protected well	0 (0)	7 (23)	10 (32)	14 (45)	31 (8)
	Protected spring	0 (0)	1 (100)	0 (0)	0 (0)	1 (0)
Unimproved	Unprotected well	0 (0)	11 (39)	5 (18)	12 (43)	28 (7)
	Bottled	2 (2)	69 (63)	28 (25)	11 (10)	110 (27)
	River	0 (0)	6 (18)	4 (12)	23 (70)	33 (8)
	Unprotected spring	0 (0)	0 (0)	0 (0)	2 (100)	2 (0)
	Trucked	0 (0)	16 (62)	3 (12)	7 (27)	26 (6)

*MPN = most probable number; HHs = households.

analysis of microbial water quality when classifying sources as improved or unimproved to better determine drinking water safety. As reported by Onda and others,⁴ data and monitoring capabilities to assess the quality of drinking water at a country level are limited.⁴ However, as described in this case study, to obtain an accurate assessment of the proportion of the population with sustainable access to clean, safe water, analysis of microbial water quality must be considered.

When we combined high risk and very high risk categories of improved sources in our study, 100 of the 210 samples from households with improved sources (47%) could be classified as microbially unsafe to drink. These findings confirm the results of previous studies documenting that improved drinking waters are not always microbially safe.⁷

Limitations of this study include that some of the drinking water sampled was from household storage containers and not directly from sources, such as pipes or wells, which increases the risk for microbial contamination because of unhygienic storage. Although the water source may have been less contaminated than the water in a storage container, persons are consuming drinking water from these storage containers and therefore exposed to any fecal microbes in such stored water.

In addition, households in this study were not selected randomly and were instead chosen based upon the presence of at least one child less than five years of age as an age group at high risk for diarrheal disease from contaminated drinking water and their accessibility for timely sample collection and transport to our water quality laboratory. Furthermore, the study was conducted during May–August, which was a period with little rainfall in 2012. The low rainfall of these months may have resulted in better microbial water quality than would occur in a rainy season because of mobilization of fecal contamination that degrades surface and ground water microbial quality.⁸

In Puerto Plata, Dominican Republic, sampled water sources that would be classified as improved by the World Health Organization/United Nations Children's Fund JMP are in fact often contaminated with concentrations of *E. coli* categorizing it as intermediate risk, high risk, or very high risk and therefore unsafe to consume. These households were unaware of the unsafe quality of their water, and actions need to be taken to build their awareness of the microbial water quality of their drinking water and to ensure their access to safe drinking water. With more than 10% of household water sources in each of the improved source categories except for protected springs (Table 2) having *E. coli* concentrations of very high risk, there are clearly opportunities for pathogen exposures that could cause negative health effects, such as diarrhea.

Microbial water quality data are necessary to determine if improved water sources are in fact safe and do not pose infectious disease risks from drinking it. Without data for the microbial quality of water, sources categorized as improved can be falsely assumed to be microbially safe when in fact they have high concentrations of *E. coli* and are likely to be unsafe.

Overall, household drinking water was not predominantly at high risk of microbial contamination for most of the households sampled throughout Puerto Plata. However, in the communities sampled, there are still a substantial pro-

portion of households in which highly microbially contaminated water is being consumed from improved water sources.

Although the Dominican Republic reported to have 82% of its population with access to an improved water source, this study provides evidence that this percentage may be an over-estimate of safe water access because it does not consider the measured microbial quality of the water. If the goal is to achieve access to safe water for the entire population, microbial water quality must be assessed globally to document quality and provide actionable data that triggers measures such as Water Safety Plans and household water treatment to better protect users from the negative health effects of unsafe, microbially contaminated water.

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REFERENCES

1. WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, 2012. *Country Reports*. Geneva: World Health Organization.
2. United Nations, 2012. *Indicators for Monitoring the Millennium Development Goals: Definitions, rationale, concepts and sources*. Available at: <http://mdgs.un.org/unsd/mi/wiki/7-8-Proportion-of-population-using-an-improved-drinking-water-source.ashx>.
3. UNICEF/WHO Joint Monitoring Programme for Water Supply and Sanitation, 2012. *Progress on Sanitation and Drinking-water: 2012 Update*. Geneva: World Health Organization.
4. Onda K, LoBuglio J, Bartram J, 2012. Global access to safe water: accounting for water quality and the resulting impact on MDG progress. *Int J Environ Res Public Health* 9: 880–894.
5. OECD/WHO, 2003. *Assessing Microbial Safety of Drinking Water: Improving Approaches and Methods*. Geneva: World Health Organization.
6. WHO, 2012. *Guidelines for Drinking-water Quality, Fourth edition*. Geneva: World Health Organization.
7. Brown J, Hien VT, McMahan L, Jenkins MW, Thie L, Liang K, Printy E, Sobsey MD, 2013. Relative benefits on on-plot water supply over other 'improved' sources in rural Vietnam. *Trop Med Int Health* 18: 65–74.
8. Johnson KM, Kumar MR, Ponnuragan P, 2010. Degradation of the quality of water during monsoon and the related outbreak of water borne diseases. *Ecol Environ Conserv* 16: 277–280.