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Extent of Fecal Contamination of Household Drinking Water in Nepal: Further Analysis of Nepal Multiple Indicator Cluster Survey 2014

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Abstract. Water sources classified as "improved" may not necessarily provide safe drinking water for householders. We analyzed data from Nepal Multiple Indicator Cluster Survey 2014 to explore the extent of fecal contamination of household drinking water. Fecal contamination was detected in 81.2% (95% confidence interval [CI]: 77.9–84.2) household drinking water from improved sources and 89.6% (95% CI: 80.4–94.7) in water samples from unimproved sources. In adjusted analysis, there was no difference in odds of fecal contamination of household drinking water between improved and unimproved sources. We observed significantly lower odds of fecal contamination of drinking water in households in higher wealth quintiles, where soap and water were available for handwashing and in households employing water treatment. The extent of contamination of drinking water as observed in this study highlights the huge amount of effort required to ensure the provision of safely managed water in Nepal by 2030 as aimed in sustainable development goals.

The 2011 census of Nepal suggested 85% of households had "improved" drinking water sources, an increase of 39% points from the 1990s.[1] These improved water sources are expected to better protect the water from extraneous contamination compared with unimproved sources. "Improved" water sources comprise water piped to premises, public taps/standpipes, tube wells or boreholes, protected wells, protected springs, and rainwater.[2] "Unimproved" sources comprise unprotected springs, unprotected wells, tanker trucks, surface waters, and bottled water.[2] But water from improved sources also have varied risk of fecal contamination, particularly in a developing country scenario such as in Nepal where poor management of water sources, household water storage practices, and water-related behaviors increase the risk of contamination.[3] The recently endorsed sustainable development goals (SDGs) intend to measure the goal of "achieving universal and equitable access to safe and affordable drinking water for all by 2030" based on the percentage of population using "safely managed drinking water services."[4] This refers to water from improved sources that are located on premises, available when needed, and free of fecal and priority chemical contamination.[4] In this study, we present the extent of fecal contamination of household drinking water and associated factors in Nepal using a nationally representative survey—Nepal Multiple Indicator Cluster Survey (NMICS) 2014.[5]

In the NMICS 2014, the number of *Escherichia coli* colony forming units (CFUs) was measured in water samples using a field-based method. A 100 mL volume of water sample was filtered through a filtration membrane (0.45 μm), and the membrane was then placed over a compact dry *E. coli* growth media plate. In addition, 1 mL water sample was directly plated on to another media plate. Media plates were incubated in a body-belt incubator or in a phase-change incubator for 24 hours. Blank tests were conducted for quality control. For further details on study methodology and water quality measurement please see final report of NMICS 2014.[5] Our analysis involved 1,421 households, randomly selected for microbiological monitoring of household drinking water and with valid test results. In addition, we analyzed 474 households of 519 households randomly selected for measurement of source water quality. Household drinking water samples were collected by asking householders to provide a glass of water as would be given to a child to drink. Source water samples were collected directly in sterile Whirl-Pak® Bags (Nasco, Fort Atkinson, WI). Our primary outcome of interest was the presence of fecal contamination which was coded "yes" if at least 1 CFU of *E. coli* was detected in 100 mL water sample tested. This outcome was chosen as absence of *E. coli* in 100 mL of drinking water, which is the new indicator for bacteriological quality of safely managed water as targeted in SDG. We also examined the level of *E. coli* contamination based on guidelines for drinking-water quality (further details on definition of fecal contamination and risk categorization is provided in Supplemental Appendix), which classifies *E. coli* risk level into high/very-high and low/moderate health risks.[5,6] Our independent variables of interest were type of water source, wealth index, location of household, season of sample collection (rainy: monsoon months and non-rainy: premonsoon months), use of boiling and/or filtration as water treatment method, presence of improved sanitation facility, and presence of water and soap at handwashing place. The wealth index is a composite indicator to capture underlying long-term wealth of households, which was calculated using information on the household's assets through the principal components analysis method.[5] First, we assessed the prevalence of fecal contamination and level of *E. coli* contamination in household drinking water and source water samples. We then examined distribution of fecal contamination by household characteristics, followed by univariate and multivariable logistic regression (Table 1). Sampling weights were used to adjust for cluster sampling design of the survey throughout the analysis. NMICS 2014 was approved by the Nepal Health Research Council.

Most (92.6%, 95% confidence interval [CI]: 90.4–94.2) of Nepalese households had access to improved water sources.

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TABLE 1
Factors associated with fecal contamination in drinking water samples at households (N = 1,421)

Characteristics	Fecal contamination % (95% CI)	Unadjusted OR (95% CI)	Adjusted OR* (95% CI)	P values	Total sample
Type of drinking water source					
Unimproved	89.6 (80.4–94.7)	1.00	1.00	0.50	106
Improved	81.2 (77.9–84.2)	0.50 (0.24–1.07)	0.77 (0.35–1.67)		1,315
Residence					
Urban	71.1 (64.2–77.1)	1.00	1.00	0.24	283
Rural	84.6 (80.9–87.6)	2.23 (1.48–3.34)	0.71 (0.40–1.25)		1,138
Season of sample collection					
Other	82.6 (79.0–85.7)	1.00	1.00	0.14	1,091
Rainy season	79.4 (71.7–85.4)	0.81 (0.49–1.31)	0.68 (0.40–1.14)		330
Water treatment method					
Neither boiling nor filtration	85.5 (82.3–88.2)	1.00	1.00	0.04	1,142
Both boiling and filtration	59.0 (42.7–73.5)	0.24 (0.12–0.48)	0.50 (0.26–0.98)		71
Boiling only	71.9 (58.5–82.4)	0.43 (0.23–0.81)	0.54 (0.29–0.99)		96
Filtration only	67.8 (55.4–78.1)	0.35 (0.20–0.62)	0.73 (0.37–1.43)		112
Sanitation facility					
Unimproved	82.0 (76.8–86.2)	1.00	1.00	0.17	613
Improved	81.8 (77.8–85.2)	0.99 (0.67–145)	1.34 (0.87–2.04)		808
Handwashing facility with soap and water†					
Not observed	91.1 (86.9–94.1)	1.00	1.00	0.03	394
Observed	78.2 (74.1–81.7)	0.35 (0.21–0.56)	0.58 (0.35–0.97)		1,019
Wealth index					
Poorest	93.2 (89.7–95.5)	1.00	1.00	< 0.001	260
Second	88.5 (83.3–92.3)	0.56 (0.30–1.04)	0.71 (0.37–1.35)		317
Middle	87.4 (80.7–92.0)	0.50 (0.26–0.99)	0.66 (0.31–1.37)		252
Fourth	80.5 (73.2–86.2)	0.30 (0.16–0.55)	0.37 (0.18–0.71)		273
Richest	62.8 (54.8–70.2)	0.12 (0.07–0.21)	0.16 (0.07–0.33)		319

CI = confidence interval; OR = odds ratio.
*Each variable adjusted for all other variables listed in the table.
†Eight households had missing observations.

Fecal contamination of household drinking water was detected in 82.0% (95% CI: 78.7–84.7) of the total households, corresponding to 81.2% (95% CI: 77.9–84.2) households with improved water sources and 89.6% (95% CI: 80.4–94.7) households with unimproved water sources. Based on risk categories, high/very-high level of fecal contamination was detected in 56.8% (95% CI: 53.0–60.5) of the total households, 55.3% (95% CI: 51.3–59.1) of households with improved water sources, and 75.5% (95% CI: 65.5–83.4) of households with unimproved water sources. The prevalence of fecal contamination in household drinking water was highest if the source was "unprotected well and spring water" (92.2%, 95% CI: 84.2–96.3) and lowest if the source was water "piped on premises" (74.4%, 95% CI: 67.7–80.2). Prevalence of fecal contamination according to other study variables is shown in Table 1. In source water samples, fecal contamination was detected in 71.6% (95% CI: 66.4–76.3) of the total samples, 70.3% (95% CI: 64.4–75.4) of improved water sources, and 83.7% (95% CI: 69.0–92.2) of unimproved water sources.

The unadjusted and adjusted odds of fecal contamination in household drinking water according to various study variables are shown in Table 1. In the multivariable model, the odds of fecal contamination of household drinking water from improved source were not different to water from unimproved sources. Compared with household drinking water without any treatment, the odds of fecal contamination were significantly lower in water subjected to "boiling" (odds ratio [OR]: 0.50, 95% CI: 0.26–0.98) and "boiling as well as filtration" (OR: 0.54, 95% CI: 0.29–0.99) but not in water that was only "filtered." Households that had soap and water available for handwashing had lower odds (OR: 0.58, 95% CI: 0.35–0.97) of fecal contamination in drinking water compared with those who did not have such a facility. The odds of fecal contamination decreased with increase in wealth status of households but was statistically significant only in fourth and richest quintile compared with poorest quintile ($P < 0.001$). We did not observe significant association of fecal contamination in household drinking water with rural/urban residence, season of sample collection, and availability of improved sanitation facility.

Fecal contamination of 82.0% of household drinking water samples in Nepal is higher than for other developing countries such as Bangladesh (61.7%), Democratic Republic of Congo (77.7%), and Ghana (62.1%).[7–9] This indicates a huge challenge in ensuring the provision of safely managed water services by 2030.[4] The fact that in 2015 Nepal experienced earthquakes killing approximately 9,000 people, destroying thousands of homes and physical infrastructure (including water and sanitation) in 14 districts (of 75 districts) makes this task even more daunting.[10] It is also important to note that four-fifths of household with access to improved water sources are drinking fecally contaminated water, and one in every two households use drinking water that has high/very-high level of fecal contamination. This result is consistent with the conclusion drawn in a systematic review by Bain and others who reported access to water from improved sources does not ensure that the water is free from fecal contamination.[11] The reasons for contamination in "improved" water sources has been well argued by Shaheed and others as the interrelationship of three factors—water storage, risks specific to piped water supplies, and household water management practices.[3] Besides substantial intra-household contamination, source water from "improved" water sources had high prevalence of fecal contamination in our sample. Our results of no significant lower odds of fecal contamination of drinking water with filtration could be due to poor performance, poor

maintenance, inconsistent use, and recontamination of the filter. This has also been reported in previously conducted studies.[12]

The study findings need to be considered against survey limitations. The NMICS 2014 did not collect data about the water treatment status at the reservoir of water; thus we cannot tell if the water collected at source was contaminated in the reservoir or in between the reservoir and source of water collection due to pipe breakage. We also cannot rule out social desirability and courtesy bias due to self-reporting of information about water treatment methods.

We conclude that the risk of fecal contamination of household drinking water in Nepal is similar irrespective of whether water is obtained from improved or unimproved source. At least four-fifths of Nepalese households are using fecally contaminated drinking water. This scenario highlights the huge need and effort required to ensure the provision of safely managed water by 2030 as targeted in SDGs. Future public health actions should focus on improving the water quality at the source and minimizing further contamination at households. Effective water treatment methods such as boiling, appropriate filtration, and disinfection should be encouraged along with tailored public health messages on sanitation and hygiene to minimize household contamination of drinking water.

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