Fecal Contamination of Drinking-Water in Low- and Middle-Income Countries: A Systematic Review and Meta-Analysis

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Background

• “Use of an improved source” is the indicator used by the Joint Monitoring Programme to monitor progress for Millennium Development Goal target 7c

• Indicator criticized for not adequately representing safety
Objective:
Investigate the status of drinking water safety (quality and safely managed) to inform post-2015 monitoring and the global burden of disease estimates.

Tasked by the JMP Water Working Group to examine:

• How safe are improved sources?

Tasked by WHO to examine:

• Global exposure to fecal contamination in drinking water
• Influence of supply type on relative quality of source and stored drinking water
• Seasonal variation of water quality in drinking water supplies
Fecal Contamination of Drinking-Water in Low- and Middle-Income Countries: A Systematic Review and Meta-Analysis

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Abstract

\textbf{Background:} Access to safe drinking-water is a fundamental requirement for good health and is also a human right. Global access to safe drinking-water is monitored by WHO and UNICEF using as an indicator “use of an improved source,” which does not account for water quality measurements. Our objectives were to determine whether water from “improved” sources is less likely to contain fecal contamination than “unimproved” sources and to assess the extent to which contamination varies by source type and setting.

\textbf{Methods and Findings:} Studies in Chinese, English, French, Portuguese, and Spanish were identified from online databases, including PubMed and Web of Science, and grey literature. Studies in low- and middle-income countries published between 1990 and August 2013 that assessed drinking-water for the presence of \textit{Escherichia coli} or thermotolerant coliforms (TTC) were included. Provide they associated results with a particular source type. In total 319 studies were included, reporting on 96,737 water samples. The odds of contamination within a given study were considerably lower for “improved” sources than “unimproved” sources (odds ratio [OR] = 0.15 [0.10–0.21], \(I^2 = 80.3\% [72.9–85.6]\)). However, over a quarter of samples from improved sources contained fecal contamination in 38% of 191 studies. Water sources in low-income countries (OR = 2.37 [1.52–3.71]; \(p<0.001\)) and rural areas (OR = 2.37 [1.47–3.81]; \(p<0.001\)) were more likely to be contaminated. Studies rarely reported stored water quality or sanitary risks and few achieved robust random selection. Safety may be overestimated due to infrequent water sampling and deterioration in quality prior to consumption.

\textbf{Conclusion:} Access to an “improved source” provides a measure of sanitary protection but does not ensure water is free of fecal contamination nor does it consistently deliver water of any specific type or safety. International estimates therefore greatly overstate use of safe drinking-water and do not fully reflect disparities in access. An enhanced monitoring strategy would combine indicators of sanitary protection with measures of water quality.
Objectives

(i) Is water from improved sources less likely to exceed health-based guidelines for microbial water quality than water from unimproved sources?

(ii) To what extent does microbial contamination vary between:
- Source types
- Between countries
- Between rural and urban areas

(iii) Are some types of water source associated with higher risk scores as assessed by sanitary inspection?
Methods

• **Included**: Studies in low and middle income countries that assessed drinking-water for *E. coli* or thermotolerant coliforms provided they disaggregated results by supply type

• **Searched**: Databases including PubMed and Web of Science; grey literature; requested submissions

• **Languages**: Chinese, English, French, Spanish and Portuguese
Search Results

• 310 studies (peer-reviewed and grey literature)
• 96,737 water samples
• Mostly cross-sectional studies (n=241, 75%), fewer longitudinal studies (n=39, 12%)

• Study quality criteria
  • Assessed bias in estimating compliance to health based guidelines
  • Possible score range: 0 to 13
  • IQR of included studies: 5 to 8
Results

• The odds of contamination within a given study were considerably lower for “improved” sources than “unimproved” sources
  • Odds ratio [OR] = 0.15 [0.10–0.21], $I^2 = 80.3\%$ [72.9–85.6]

• Over a quarter of samples from improved sources contained fecal contamination
  • Protected dug wells rarely free of contamination

• Water sources in low-income countries (OR = 2.37 [1.52–3.71]; $p<0.001$) and rural areas (OR = 2.37 [1.47–3.81] $p<0.001$) were more likely to be contaminated
Results

• Few studies in non-household settings (schools, health facilities, workplaces)

• Studies rarely reported stored water quality or sanitary risks and few achieved robust random selection

• Safety may be overestimated due to infrequent water sampling and deterioration in quality prior to consumption
Related studies
Global assessment of exposure to faecal contamination through drinking water based on a systematic review

Robert Bain¹, Ryan Cronk¹, Rifat Hossain², Sophie Bonjour³, Kyle Onda¹, Jim Wright³, Hong Yang³, Tom Slaymaker⁴, Paul Hunter⁵, Annette Prüss-Ustün² and Jamie Bartram¹

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Abstract

OBJECTIVES To estimate exposure to faecal contamination through drinking water as indicated by levels of *Escherichia coli* (*E. coli*) or thermotolerant coliform (TTC) in water sources.

METHODS We estimated coverage of different types of drinking water source based on household surveys and censuses using multilevel modelling. Coverage data were combined with water quality studies that assessed *E. coli* or TTC including those identified by a systematic review (*n* = 345). Predictive models for the presence and level of contamination of drinking water sources were developed using random effects logistic regression and selected covariates. We assessed sensitivity of estimated exposure to study quality, indicator bacteria and separately considered nationally randomised surveys.

RESULTS We estimate that 1.8 billion people globally use a source of drinking water which suffers from faecal contamination, of these 1.1 billion drink water that is of at least ‘moderate’ risk (>10 *E. coli* or TTC per 100 ml). Data from nationally randomised studies suggest that 10% of improved sources may be ‘high’ risk, containing at least 100 *E. coli* or TTC per 100 ml. Drinking water is found to be more often contaminated in rural areas (41%, CI: 31%–51%) than in urban areas (12%, CI: 7%–18%).
Global assessment of exposure to fecal contamination through drinking water: methods

- Developed predictive models to estimate the presence and level of contamination of drinking water sources
  - Methods: random effects logistic regression and selected covariates
- Assessed sensitivity of estimated exposure to study quality, indicator bacteria and separately considered nationally randomized surveys
Exposure to fecal contamination in drinking water

- 1.8 billion use a contaminated water source
- 1.1 billion sources are moderate risk (> 10 *E. coli* or TTC per 100 ml)
- 10% of improved sources high risk (> 100 EC or TTC per 100 ml; estimated from nationally randomized surveys)

Graphic from the 2014 JMP report available at wssinfo.org
The worst environmental problem in today's world? More than 1 billion people drink their neighbours lukewarm feces: onlinelibrary.wiley.com/doi/10.1111/tm...
Influence of supply type on relative quality of source and stored drinking water in developing countries: a bivariate meta-analysis

Katherine Shields, Rob Bain Ryan Cronk, Jim Wright, Jamie Bartram
(Under Review)
Does water quality at the point of collection and in household stored water depend on water supply type?
Results

• Analyzed 45 studies (out of 319, 14%)

• Non-compliance:
  • At the source: 46%
  • Household stored water: 75%

• Water supply type was significantly associated with noncompliance at the source (p < .0001) and in household stored water (p = 0.0275).

• Source water (OR = 5.3 [95% CI: 1.9, 14.9]) and household stored water (OR = 3.1 [95% CI: 1.2, 8.5]) from non-piped supplies had significantly higher odds of contamination when compared to stored piped water.
Seasonal variation of fecal contamination in drinking water sources in developing countries

Caroline Kostyla, Rob Bain, Ryan Cronk, Jamie Bartram
Seasonality

• Analyzed 22 studies (out of 319, 7%)
• Fecal contamination in improved drinking water sources was shown to follow a statistically significant seasonal trend of greater contamination during the wet season.
• This trend was consistent across the fecal indicator bacteria, five source types, twelve Köepper-Geiger climate zones, and in rural and urban settings.
Conclusion

Improved sources

• Access to an “improved source” provides a measure of sanitary protection but does not ensure water is free of fecal contamination nor is it consistent between source types or settings.

• International estimates therefore greatly overstate use of safe drinking-water and do not fully reflect disparities in access.

• An enhanced monitoring strategy would combine indicators of sanitary protection with measures of water quality.

Exposure to fecal contamination in drinking water

• Global burden of disease estimates may have substantially understated the disease burden associated with inadequate water services.
Conclusion

**Stored water**
- Piped water is less likely to be contaminated compared to other water supply types at both the source and in household stored water.
- A focus on upgrading water services to piped supplies will help improve safety, including for those drinking stored water.

**Seasonality**
- Temporal spacing guidelines to ensure seasonally representative water quality sampling could improve assessments of global access to safe drinking water.

**Non-household settings**
- Don’t forget about safe water and safe storage in schools, health care facilities, and workplaces.
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Thanks for your attention.

Questions?

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Photo: Kaida Liang, 2013