Effect of water, sanitation, and hygiene interventions on detection of enteropathogens and host-specific fecal markers in the environment: an individual-participant data meta-analysis

Andrew Mertens, Benjamin F. Arnold, Jade Benjamin-Chung, Alexandria Boehm, Joe Brown, Drew Capone, Thomas Clasen, Erica Fuhrmeister, Jessica Grembi, David Holcomb, Jackie Knee, Laura Kwong, Audrie Lin, Stephen P. Luby, Rassul Nala, Kara Nelson, Sammy Njenga, Clair Null, Amy J. Pickering, Mahbubur Rahman, Heather Reese, Lauren Steinbaum, Jill Stewart, Ruwan Thilakaratne, Oliver Cumming, John M. Colford Jr., Ayse Ercumen

# Supplementary FIGURES AND TABLES

## 



\*One unpublished and shared by authors of another included study

The systematic review was conducted on 1/19/2021.

**Figure S1.** PRISMA Flowchart.

## A picture containing table Description automatically generated

## Figure S2. Forest plots of intervention effects on the prevalence of specific pathogens.

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Chart

Description automatically generated with medium confidence

**Figure S3.** Forest plots of intervention effects on the prevalence of specific MST markers.

Chart

Description automatically generated

Chart

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Chart, histogram

Description automatically generated

Chart

Description automatically generated

Chart

Description automatically generated

**Figure S4.** Distributions of abundance outcomes. The X-axes are displayed on the log-10 scale. Black vertical lines mark the means, and dashed lines mark the medians. Values below the limit of detection were imputed with with half the limit of detection and values below the limit of quantification were imputed with the midpoint between the limits of detections and quantification, leading to some bimodal distributions.

Chart

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**Figure S5.** Forest plots of any enteropathogen prevalence differences or any MST prevalence differences between intervention and control arms, stratified by whether the sample was collected during the wet versus dry season (defined by the 6 months of highest average rainfall). Significant effect modification, as determined by the p-values on the regression model interaction term, is marked above points with asterisks (P < 0.05 = “\*”, P < 0.01 = “\*\*”, P < 0.001 = “\*\*\*”). Grey crossed points denote data that were too sparse to estimate a prevalence ratio (i.e., <10 positive observations).

Chart

Description automatically generated

**Figure S6.** Forest plots of any enteropathogen prevalence differences or any MST prevalence differences between intervention and control arms, stratified by whether any animals were present in the compound. Significant effect modification, as determined by the p-values on the regression model interaction term, is marked above points with asterisks (P < 0.05 = “\*”, P < 0.01 = “\*\*”, P < 0.001 = “\*\*\*”). Grey crossed points denote data that were too sparse to estimate a prevalence ratio (i.e., <10 positive observations).

Chart

Description automatically generated with medium confidence

**Figure S7.** Forest plots of any enteropathogen prevalence differences or any MST prevalence differences between intervention and control arms, stratified by whether the pathogen is zoonotically transmitted. Grey crossed points denote data that were too sparse to estimate a prevalence ratio (i.e., <10 positive observations). Significant effect modification, as determined by the p-values on the regression model interaction term, is marked above points with asterisks (P < 0.05 = “\*”, P < 0.01 = “\*\*”, P < 0.001 = “\*\*\*”). Grey crossed points denote data that were too sparse to estimate a prevalence ratio (i.e., <10 positive observations).

Chart, scatter chart

Description automatically generated

**Figure S8.** Forest plots of unadjusted intervention effects on the prevalence of any enteropathogen or type of enteropathogen (any bacteria, any virus, any protozoa and any STH) in different types of environmental samples. Point estimates and confidence intervals are printed next to pooled estimates. Grey crossed points denote data that were too sparse to estimate a prevalence ratio (i.e., <10 positive observations).

Chart

Description automatically generated

**Figure S9.** Forest plots of unadjusted intervention effects on the prevalence of any MST marker or type of MST marker (human or animal MST markers) in different types of environmental samples. Point estimates and confidence intervals are printed next to pooled estimates. Grey crossed points denote data that were too sparse to estimate a prevalence ratio (i.e., <10 positive observations).

## Table S1. Systematic review search terms

Search terms were combined with “OR” within columns and with “AND” across columns.

| **Study design** | **WASH** | **Environmental markers** | **Child health** |
| --- | --- | --- | --- |
| matched, trial, RCT, experiment, intervention, randomized, randomised, quasi-randomized, quasi-randomised, quasi-experimental, pseudo-randomized, pseudo-randomised, non-randomized controlled trials | Water, Sanitation, Hygiene, Handwashing, WSH, Sanitation, Water Supply, Sanitary Drainage, Toilet Facilities, Drinking Water, Hand Hygiene, Water Purification, Waste Water, disinfection | molecular source tracking, microbial source tracking, microbial transmission, diarrheal pathogen, diarrheal pathogens, diarrhoeal pathogen, diarrhoeal pathogens, fecal-oral, faecal-oral, entericpathogen, entericpathogens, ruminant, avian, Feces, Faeces, Fecal, Faecal, Fecally, Faecally | Entericinfection, Soil-transmitted helminth, Protozoan, Seroconversion, Fecal microbiology, Faecal microbiology, Fecal biomarker, Faecal biomarker, Intestinal Diseases, Parasitic, Seroconversion, Enteritis, Helminthiasis, Helminthiases, Intestinal infection, Viral infection, Bacterial infection, Parasite infection, Parasitic infection, Helminth infection, Fecal sampling, Faecal sampling, Stool sampling, Stool collection, Diarrhea, Dysentery, Child growth faltering, Growth faltering, Child development, Length-for-age, Height-for-age, Weight-for-age, Head circumference, Waist circumference, Stunting, Stunted, Wasting, Wasted, Linear growth, Anthropometric measurement, Malnutrition, Undernourished, Undernutrition, Underweight, Growth Disorders, Childnutrition disorder, Wasting syndrome, Thinness, Growth velocity |

## 

## Table S2. Pubmed search string

[MH] are mesh headers and [TW] are text words.

|  |
| --- |
| ((matched [tw]) OR (trial [tw]) OR (RCT [tw]) OR (experiment [tw]) OR (intervention [tw]) OR (randomized [tw]) OR (randomised [tw]) OR (quasi-randomized [tw]) OR (quasi-randomised [tw]) OR (quasi-experimental [tw]) OR (pseudo-randomized [tw]) OR (pseudo-randomised [tw]) OR (“non-randomized controlled trials as topic” [mh])) AND ((Water [tw]) OR (Sanitation [tw]) OR (Hygiene [tw]) OR (Handwashing [tw]) OR (WSH [tw]) OR (“Sanitation” [mh]) OR (“Water Supply” [mh]) OR (“Drainage, Sanitary” [mh]) OR (Sanitary Drainage [tw]) OR (“Toilet Facilities” [mh]) OR (“Drinking Water” [mh]) OR (“Hand Hygiene” [mh]) OR (“Water Purification” [mh]) OR (“Waste Water” [mh]) OR (disinfect\* [tw])) AND ((molecular source tracking [tw]) OR (microbial source tracking [tw]) OR (microbial transmission [tw]) OR (diarrheal pathogen [tw]) OR (diarrheal pathogens [tw]) OR (diarrhoeal pathogen [tw]) OR (diarrhoeal pathogens [tw]) OR (fecal-oral [tw]) OR (faecal-oral [tw]) OR (enteric pathogen [tw]) OR (enteric pathogens [tw]) OR (ruminant\* [tw]) OR (avian\* [tw]) OR (“Feces” [mh]) OR (Feces [tw]) OR (Faeces [tw]) OR (Fecal [tw]) OR (Faecal [tw]) OR (Fecally [tw]) OR (Faecally [tw])) AND (((Enteric infection\* [tw]) OR (Soil-transmitted helminth\* [tw]) OR (Protozoan\* [tw]) OR (Seroconversion [tw]) OR (Fecal microbio\* [tw]) OR (Faecal microbio\* [tw]) OR (Fecal biomarker\* [tw]) OR (Faecal biomarker\* [tw]) OR (“Intestinal Diseases, Parasitic/epidemiology” [mh]) OR (“Seroconversion” [mh]) OR (Seroconversion [tw]) OR (“Enteritis/epidemiology” [mh]) OR (“Helminthiasis/complications” [mh]) OR (Helminthiasis [tw]) OR (Helminthiases)OR (“Helminthiasis/epidemiology” [mh]) OR (“Helminthiasis/prevention and control” [mh]) OR (Intestinal infection\* [tw]) OR (Viral infection\* [tw]) OR (Bacterial infection\* [tw]) OR (Parasite infection\* [tw]) OR (Parasitic infection\* [tw]) OR (Helminth infection\* [tw]) OR (Fecal sampling [tw]) OR (Faecal sampling [tw]) OR (Bacterial infection\* [tw]) OR (Parasite infection\* [tw]) OR (Parasitic infection\* [tw]) OR (Helminth infection\* [tw]) OR (Fecal sampling [tw]) OR (Faecal sampling [tw]) OR (Stool sampling [tw]) OR (Stool collection [tw])) OR ((Diarrh\* [tw]) OR (Dysentery [tw]) OR (“Diarrhea/epidemiology” [mh]) OR (“Diarrhea/etiology” [mh]) OR (“Diarrhea/prevention and control” [mh]) OR (“Diarrhea, Infantile” [mh]) OR (“Dysentery” [mh])) OR (Child growth faltering [tw]) OR (Growth faltering [tw])OR (Child development [tw]) OR (Length-for-age [tw]) OR (Height-for-age [tw]) OR (Weight-for-age [tw]) OR (Head circumference [tw]) OR (Waist circumference [tw]) OR (Stunt\* [tw]) OR (Wasting [tw]) OR (Wasted [tw]) OR (Linear growth [tw]) OR (Anthropometric measurement\* [tw]) OR (Maln\* [tw]) OR (Undernourish\* [tw]) OR (Undernutrition [tw]) OR (Underweight [tw]) OR (“Growth Disorders” [mh]) OR (Growth Disorders [tw]) OR (“Child nutrition disorders” [mh]) OR (Child nutrition disorder\* [tw]) OR (“Malnutrition” [mh]) OR (“Wasting Syndrome” [mh]) OR (Wasting syndrome [tw]) OR (“Thinness” [mh]) OR (Thinness [tw]) OR (Growth velocity [tw])) |

## 

## Table S3. PRISMA Checklist

| **Topic** | **No.** | **Item** | **Location where item is reported** |
| --- | --- | --- | --- |
| **TITLE** |  |  |  |
| **Title** | 1 | Identify the report as a systematic review. | Page 1 |
| **ABSTRACT** |  |  |  |
| **Abstract** | 2 | See the PRISMA for Abstracts checklist below |  |
| **INTRODUCTION** |  |  |  |
| **Rationale** | 3 | Describe the rationale for the review in the context of existing knowledge. | Line 101-112 |
| **Objectives** | 4 | Provide an explicit statement of the objective(s) or question(s) the review addresses. | Line 116-119 |
| **METHODS** |  |  |  |
| **Eligibility criteria** | 5 | Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses. | Line 123-133 |
| **Information sources** | 6 | Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted. | Line 122-123, Fig. S1 |
| **Search strategy** | 7 | Present the full search strategies for all databases, registers and websites, including any filters and limits used. | Tables S1-S2 |
| **Selection process** | 8 | Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process. | Line 130-133 |
| **Data collection process** | 9 | Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process. | Line 135-138 |
| **Data items** | 10a | List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect. | Line 135-151 |
|  | 10b | List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information. | Line 135-151 |
| **Study risk of bias assessment** | 11 | Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process. | Line 132-133 |
| **Effect measures** | 12 | Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results. | Line 152-203 |
| **Synthesis methods** | 13a | Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item 5)). | Line 139-151 |
|  | 13b | Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions. | Line 139-173 |
| 13c | Describe any methods used to tabulate or visually display results of individual studies and syntheses. | Figure captions |
| 13d | Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used. | Line 161-193 |
| 13e | Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression). | Line 180-200 |
| 13f | Describe any sensitivity analyses conducted to assess robustness of the synthesized results. | Line 326-327 |
| **Reporting bias assessment** | 14 | Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases). | Not applicable |
| **Certainty assessment** | 15 | Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome. | Not applicable |
| **RESULTS** |  |  |  |
| **Study selection** | 16a | Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram. | Figure S1 |
|  | 16b | Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded. | Line 212-214 |
| **Study characteristics** | 17 | Cite each included study and present its characteristics. | Line 219-230, Table 1 |
| **Risk of bias in studies** | 18 | Present assessments of risk of bias for each included study. | Table S4 |
| **Results of individual studies** | 19 | For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots. | Figures1 ,2 S2-S3, S5-S8, Tables 2, S6-S9 |
| **Results of syntheses** | 20a | For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies. | Not applicable |
|  | 20b | Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect. | Figures1 ,2 S2-S3, S5-S8, Tables 2, S6-S9 |
| 20c | Present results of all investigations of possible causes of heterogeneity among study results. | Line 318-327 |
| 20d | Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results. | Line 326-327 |
| **Reporting biases** | 21 | Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed. | Not applicable |
| **Certainty of evidence** | 22 | Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed. | Figures1 ,2 S2-S3, S5-S8, Tables 2, S6-S9 |
| **DISCUSSION** |  |  |  |
| **Discussion** | 23a | Provide a general interpretation of the results in the context of other evidence. | Line 330-359 |
|  | 23b | Discuss any limitations of the evidence included in the review. | Line 384-405 |
| 23c | Discuss any limitations of the review processes used. | Line 406-410 |
| 23d | Discuss implications of the results for practice, policy, and future research. | Line 415-424 |
| **OTHER INFORMATION** |  |  |  |
| **Registration and protocol** | 24a | Provide registration information for the review, including register name and registration number, or state that the review was not registered. | https://osf.io/8sgzn/ |
|  | 24b | Indicate where the review protocol can be accessed, or state that a protocol was not prepared. | https://osf.io/8sgzn/ |
| 24c | Describe and explain any amendments to information provided at registration or in the protocol. | Not applicable |
| **Support** | 25 | Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review. | Line 36 |
| **Competing interests** | 26 | Declare any competing interests of review authors. | Not applicable |
| **Availability of data, code and other materials** | 27 | Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review. | https://github.com/amertens/wash-ipd |

# 

| **Topic** | **No.** | **Item** | **Reported?** |
| --- | --- | --- | --- |
| **TITLE** |  |  |  |
| **Title** | 1 | Identify the report as a systematic review. | Yes |
| **BACKGROUND** |  |  |  |
| **Objectives** | 2 | Provide an explicit statement of the main objective(s) or question(s) the review addresses. | Yes |
| **METHODS** |  |  |  |
| **Eligibility criteria** | 3 | Specify the inclusion and exclusion criteria for the review. | Yes |
| **Information sources** | 4 | Specify the information sources (e.g. databases, registers) used to identify studies and the date when each was last searched. | No |
| **Risk of bias** | 5 | Specify the methods used to assess risk of bias in the included studies. | Yes |
| **Synthesis of results** | 6 | Specify the methods used to present and synthesize results. | Yes |
| **RESULTS** |  |  |  |
| **Included studies** | 7 | Give the total number of included studies and participants and summarise relevant characteristics of studies. | Yes |
| **Synthesis of results** | 8 | Present results for main outcomes, preferably indicating the number of included studies and participants for each. If meta-analysis was done, report the summary estimate and confidence/credible interval. If comparing groups, indicate the direction of the effect (i.e. which group is favoured). | Yes |
| **DISCUSSION** |  |  |  |
| **Limitations of evidence** | 9 | Provide a brief summary of the limitations of the evidence included in the review (e.g. study risk of bias, inconsistency and imprecision). | Yes |
| **Interpretation** | 10 | Provide a general interpretation of the results and important implications. | Yes |
| **OTHER** |  |  |  |
| **Funding** | 11 | Specify the primary source of funding for the review. | Yes |
| **Registration** | 12 | Provide the register name and registration number. | Yes |

| **Reference** Table S4. Risk of bias based on modified Newcastle-Ottawa scaleStars are given for low risk of bias in each category, up to a total of nine stars. Scoring details are in the footnotes. | **Selection bias** | **Response bias** | **Follow-up bias** | **Misclassification bias** | **Outcome assessment** |  | **Outcome measurement** | **Bias in analysis** | **Total** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Is there evidence of selection bias, which refers to systematic differences between baseline characteristics of the groups that are compared?a | Is there evidence of response bias?b | Is there evidence of bias due to missing follow-up data?c | Is there risk of households not receiving the intervention being misclassified as having received it, or vice versa?d | Is there evidence of bias arising from how the outcome was assessed?e |  | Is there evidence of ascertainment bias?f | Is there evidence that analysis was not appropriately adjusted for clustering and/or confounding, if appropriate?g | Total number of stars (x/9 possible stars). |
| Clasen T, et al. Effectiveness of a rural sanitation programme on diarrhoea, soil-transmitted helminth infection, and child malnutrition in Odisha, India: a cluster-randomised trial. Lancet Glob Health. 2014. | \* | \* no, laboratory assessed and blinded | possible (86% of possible weeks are reported weeks) | \* household-level interventions | \*\* |  | \* | \*\* adjusted for clustering | 8 |
| Luby, S.P. et al.. Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural Bangladesh: a cluster randomised controlled trial. The Lancet Global Health 2018 | \* | \* no, laboratory assessed and blinded | \* 94% complete FU | \* household-level interventions | \*\* |  | \* | \*\* | 9 |
| Null, C. et al., Effects of water quality, sanitation, handwashing, and nutritional interventions on diarrhoea and child growth in rural Kenya: a cluster-randomised controlled trial. The Lancet Global Health 2018 | \* | \* no, laboratory assessed and blinded | \* <1% loss to FU | \* household-level interventions | \*\* |  | \* | \*\* | 9 |
| Reese, H. et al. Assessing longer-term effectiveness of a combined household-level piped water and sanitation intervention on child diarrhoea, acute respiratory infection, soil-transmitted helminth infection and nutritional status: a matched cohort study in rural Odisha, India. International journal of epidemiology 2019 | selection bias is possible, as the study is not randomized and there are some baseline differences between intervention and control group | \* no, laboratory assessed and blinded | substantial loss to FU | \* household-level interventions | \*\* |  | \* | \*\* | 7 |
| Knee, J. et al. Effects of an urban sanitation intervention on childhood enteric infection and diarrhea in Maputo, Mozambique: A controlled before-and-after trial. eLife 2011 | selection bias is possible, as the study is not randomized, but intervention and control groups were mostly balanced at baseline. Control households were more likely to have covered floors and higher quality walls and intervention groups had more people per household. | \* no, laboratory assessed and blinded | substantial loss to FU | \* household-level interventions | \*\* |  | \* | \*\* | 7 |

a RCTs receive 1 star, unless evidence of selection bias (e.g. randomisation procedures not followed). Meaningful differences between groups at baseline in RCTs receive 0 stars. Rates of declining to participate >10% receive 0 stars. Non- or quasi-randomised studies receive 0 stars.

b If intervention recipient was not blinded to intervention status, 0 stars.

c <10% receives 1 star, greater than or equal to 10% receives 0 stars.

d Interventions delivered at the household/individual level receive 1 star. Interventions delivered at the community level that missed a substantial, i.e. greater than or equal to 10%, proportion of the target population receive 0 stars, including when there is insufficient information to verify whether this is the case. Interventions with substantial risk of contamination (control households receiving intervention) receive 0 stars.

e Parent / person recall (=0 stars). Fieldworker assessed (=1 star). Physician/microbiologically assessed (=2 stars)

f If outcome measurement staff were not blinded to intervention status, 0 stars.

g Scoring is based on losing stars (max. 2). Individual RCTs with baseline balance on covariates are unlikely to require adjustment (=2 stars). Cluster-RCTs and non-randomised trials may require adjustment for clustering (-1 star if not done). RCTs or cRCTs may require adjustment for covariates, with justification (-1 star if not done). Non-randomised studies require adjustment for covariates (-1 star if not done), but also adequate justification for covariate selection (-1 star if not included), and there can be too few or too many covariates.

| **Study** Table S5. Prevalence of pathogens by sample type tested in each study | **Sample** | **Target** | **Percent positive (n/N)** | **PR (95% CI)** |
| --- | --- | --- | --- | --- |
| Odagiri 2016 | Source water | V. cholerae | 31.7% (19/60) | 0.73 (0.34, 1.57) |
| - | - | Adenovirus | 8.3% (5/60) | 0.25 (0.03, 2.19) |
| - | - | Rotavirus | 23.3% (14/60) | 0.75 (0.29, 1.93) |
| Boehm 2016 | Stored water | Rotavirus | 0.6% (3/493) | - |
| - | Child hand rinse | Rotavirus | 6.1% (30/493) | - |
| - | House soil | Rotavirus | 1.4% (7/496) | 2.52 (0.51, 12.42) |
| Reese 2017 | Source water | Shigella | 10.7% (161/1499) | 0.73 (0.46, 1.15) |
| - | - | V. cholerae | 13% (36/276) | 0.93 (0.46, 1.85) |
| - | Stored water | Shigella | 10.1% (190/1874) | 1.08 (0.77, 1.51) |
| - | - | V. cholerae | 23.7% (100/422) | 1.03 (0.66, 1.6) |
| Steinbaum 2019 | House soil | Ascaris | 13% (273/2107) | 0.88 (0.68, 1.13) |
| - | - | Trichuris | 6.9% (146/2107) | 0.86 (0.6, 1.23) |
| Fuhrmeister 2020 | Stored water | Pathogenic E. coli | 38.6% (286/741) | 1 (0.84, 1.19) |
| - | Child hand rinse | Pathogenic E. coli | 34% (127/373) | - |
| - | - | Giardia | 4.8% (15/311) | - |
| - | - | Norovirus | 4.2% (14/337) | - |
| - | Mother's hand rinse | Pathogenic E. coli | 24% (177/737) | - |
| - | - | Giardia | 2.3% (14/602) | - |
| - | - | Norovirus | 3.1% (21/684) | - |
| - | House soil | Pathogenic E. coli | 61.3% (453/739) | 0.94 (0.84, 1.06) |
| Capone 2021 | Latrine soil | C. difficile | 14.8% (13/88) | 0.9 (0.32, 2.48) |
| - | - | Campylobacter | 6.8% (6/88) | 2.09 (0.4, 11.05) |
| - | - | Pathogenic E. coli | 56.8% (50/88) | 0.89 (0.56, 1.42) |
| - | - | Salmonella | 6.8% (6/88) | 0.52 (0.1, 2.76) |
| - | - | Shigella | 21.6% (19/88) | 0.28 (0.1, 0.78) |
| - | - | V. cholerae | 0% (0/88) | - |
| - | - | Yersinia | 4.5% (4/88) | - |
| - | - | Ascaris | 60.2% (53/88) | 0.65 (0.41, 1.02) |
| - | - | Trichuris | 17% (15/88) | 0.92 (0.36, 2.33) |
| - | - | Cryptosporidium | 8% (7/88) | 0.78 (0.18, 3.36) |
| - | - | Entamoeba histolytica | 1.1% (1/88) | - |
| - | - | Giardia | 31.8% (28/88) | 0.47 (0.21, 1.07) |
| - | - | Adenovirus | 20.5% (18/88) | 0.21 (0.06, 0.68) |
| - | - | Astrovirus | 29.5% (26/88) | 1.27 (0.67, 2.43) |
| - | - | Norovirus | 2.3% (2/88) | - |
| - | - | Rotavirus | 4.5% (4/88) | - |
| - | - | Sapovirus | 0% (0/88) | - |
| Capone 2022 in prep | Flies | Campylobacter | 1.2% (1/86) | - |
| - | - | Pathogenic E. coli | 30.2% (26/86) | - |
| - | - | Shigella | 2.3% (2/86) | - |
| - | - | V. cholerae | 2.3% (2/86) | - |
| - | - | Ascaris | 0% (0/86) | - |
| - | - | Trichuris | 3.5% (3/86) | - |
| - | - | Giardia | 4.7% (4/86) | - |
| - | - | Adenovirus | 4.7% (4/86) | - |
| - | - | Astrovirus | 0% (0/86) | - |
| - | - | Norovirus | 2.3% (2/86) | - |
| - | - | Pan enterovirus | 0% (0/86) | - |
| - | - | Rotavirus | 1.2% (1/86) | - |
| - | - | Sapovirus | 0% (0/86) | - |
| Kwong 2021 | House soil | Ascaris | 62.1% (886/1426) | 0.97 (0.87, 1.08) |
| - | - | Trichuris | 56% (798/1426) | 1.03 (0.91, 1.15) |

## 

| **Study** Table S6. Prevalence of microbial source tracking markers by sample type tested in each study | **Sample** | **Target** | **Percent positive (n/N)** | **PR (95% CI)** |
| --- | --- | --- | --- | --- |
| Odagiri 2016 | Source water | Animal (BacCow) | 91.7% (55/60) | 1.04 (0.89, 1.21) |
| - | - | Human (BacHum) | 71.7% (43/60) | 1.05 (0.76, 1.45) |
| Boehm 2016 | Stored water | Avian (GFD) | 9.3% (46/493) | 0.71 (0.37, 1.36) |
| - | - | Ruminant (BacR) | 21.9% (108/493) | 0.62 (0.43, 0.9) |
| - | - | Human (HumM2) | 0% (0/493) | - |
| - | Child hand rinse | Avian (GFD) | 16.2% (80/493) | - |
| - | - | Ruminant (BacR) | 54.2% (267/493) | - |
| - | - | Human (HumM2) | 2.4% (12/493) | - |
| - | House soil | Avian (GFD) | 33.3% (165/496) | 0.98 (0.76, 1.27) |
| - | - | Ruminant (BacR) | 66.7% (331/496) | 0.98 (0.85, 1.12) |
| - | - | Human (HumM2) | 8.9% (44/496) | 0.94 (0.5, 1.75) |
| Fuhrmeister 2020 | Stored water | Animal (BacCow) | 68.5% (482/704) | 0.97 (0.87, 1.08) |
| - | - | Human (HumM2) | 2.6% (17/651) | 0.44 (0.16, 1.23) |
| - | Child hand rinse | Animal (BacCow) | 97.5% (356/365) | - |
| - | - | Human (HumM2) | 21.9% (74/338) | - |
| - | Mother's hand rinse | Animal (BacCow) | 96.7% (702/726) | - |
| - | - | Human (HumM2) | 18.1% (118/651) | - |
| - | House soil | Animal (BacCow) | 90.6% (572/631) | 0.99 (0.94, 1.04) |
| - | - | Human (HumM2) | 20.1% (127/631) | 1.24 (0.91, 1.7) |
| Holcomb 2021 | Source water | Avian (GFD) | 0% (0/41) | - |
| - | - | Human (HF183) | 2.4% (1/41) | - |
| - | - | Human (M. smithii) | 0% (0/41) | - |
| - | Stored water | Avian (GFD) | 1.1% (1/94) | - |
| - | - | Human (HF183) | 14.9% (14/94) | 1.72 (0.57, 5.18) |
| - | - | Human (M. smithii) | 0% (0/94) | - |
| - | Latrine soil | Avian (GFD) | 3.3% (2/60) | - |
| - | - | Human (HF183) | 50% (30/60) | 0.88 (0.51, 1.52) |
| - | - | Human (M. smithii) | 45% (27/60) | 0.74 (0.36, 1.55) |
| - | House soil | Avian (GFD) | 3.6% (3/83) | - |
| - | - | Human (HF183) | 42.2% (35/83) | 0.81 (0.49, 1.34) |
| - | - | Human (M. smithii) | 24.1% (20/83) | 1.3 (0.62, 2.73) |
| Capone 2022 in prep | Flies | Animal (BacCow) | 12.8% (11/86) | - |
| - | - | Dog (BacCan) | 30.2% (26/86) | - |
| - | - | Human (BacHum) | 72.1% (62/86) | - |

## 

| **Study** Table S7. Unadjusted and adjusted results by study, sample type, and aggregated variables for pathogen targets  (any pathogen, any bacteria, any viruses, any protozoa, any STH). | **Target** | **Sample** | **Positive, Intervention** | **Negative, Intervention** | **Positive, Control** | **Negative, Control** | **Total observations** | **Unadjusted Prevalence Ratio** | **Unadjusted p-value** | **Adjusted Prevalence Ratio** | **Adjusted p-value** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Capone 2022 in prep | Any pathogen | Any sample | 7 | 13 | 20 | 17 | 57 | PR=0.65 (95% CI: 0.33, 1.28) | 0.21 | PR=0.5 (95% CI: 0.21, 1.19) | 0.12 |
| Capone 2021 | Any pathogen | Any sample | 37 | 6 | 43 | 2 | 88 | PR=0.9 (95% CI: 0.78, 1.03) | 0.13 | PR=0.9 (95% CI: 0.78, 1.03) | 0.13 |
| Fuhrmeister 2020 | Any pathogen | Any sample | 314 | 136 | 348 | 123 | 921 | PR=0.94 (95% CI: 0.87, 1.02) | 0.17 | PR=0.94 (95% CI: 0.87, 1.02) | 0.13 |
| Steinbaum 2019 | Any pathogen | Any sample | 206 | 979 | 173 | 707 | 2,065 | PR=0.88 (95% CI: 0.7, 1.11) | 0.29 | PR=0.87 (95% CI: 0.7, 1.09) | 0.24 |
| Reese 2017 | Any pathogen | Any sample | 185 | 792 | 238 | 825 | 2,040 | PR=0.85 (95% CI: 0.66, 1.08) | 0.18 | PR=0.86 (95% CI: 0.68, 1.09) | 0.21 |
| Boehm 2016 | Any pathogen | Any sample | 19 | 229 | 15 | 234 | 497 | PR=1.27 (95% CI: 0.6, 2.68) | 0.53 | PR=1.28 (95% CI: 0.62, 2.66) | 0.5 |
| Odagiri 2016 | Any pathogen | Any sample | 12 | 18 | 15 | 15 | 60 | PR=0.8 (95% CI: 0.45, 1.42) | 0.45 |  |  |
| Reese 2017 | Any pathogen | Source water | 68 | 588 | 122 | 747 | 1,525 | PR=0.74 (95% CI: 0.49, 1.12) | 0.15 | PR=0.74 (95% CI: 0.5, 1.12) | 0.16 |
| Odagiri 2016 | Any pathogen | Source water | 12 | 18 | 15 | 15 | 60 | PR=0.8 (95% CI: 0.45, 1.42) | 0.45 |  |  |
| Fuhrmeister 2020 | Any pathogen | Stored water | 138 | 218 | 148 | 237 | 741 | PR=1.01 (95% CI: 0.85, 1.2) | 0.93 | PR=1 (95% CI: 0.84, 1.19) | 0.97 |
| Reese 2017 | Any pathogen | Stored water | 134 | 786 | 147 | 860 | 1,927 | PR=1 (95% CI: 0.75, 1.32) | 0.99 | PR=1.01 (95% CI: 0.77, 1.34) | 0.94 |
| Boehm 2016 | Any pathogen | Stored water | 2 | 243 | 1 | 245 | 491 | Not estimated |  | Not estimated |  |
| Kwong 2021 | Any pathogen | House soil | 363 | 125 | 687 | 221 | 1,396 | PR=0.98 (95% CI: 0.91, 1.06) | 0.67 | PR=0.98 (95% CI: 0.91, 1.06) | 0.68 |
| Fuhrmeister 2020 | Any pathogen | House soil | 217 | 144 | 236 | 142 | 739 | PR=0.96 (95% CI: 0.86, 1.08) | 0.53 | PR=0.94 (95% CI: 0.84, 1.06) | 0.31 |
| Steinbaum 2019 | Any pathogen | House soil | 209 | 1,000 | 173 | 725 | 2,107 | PR=0.9 (95% CI: 0.72, 1.13) | 0.35 | PR=0.89 (95% CI: 0.71, 1.11) | 0.31 |
| Boehm 2016 | Any pathogen | House soil | 5 | 242 | 2 | 247 | 496 | PR=2.52 (95% CI: 0.51, 12.42) | 0.26 | PR=2.52 (95% CI: 0.51, 12.42) | 0.26 |
| Capone 2021 | Any pathogen | Latrine soil | 37 | 6 | 43 | 2 | 88 | PR=0.9 (95% CI: 0.78, 1.03) | 0.13 | PR=0.9 (95% CI: 0.78, 1.03) | 0.13 |
| Capone 2022 in prep | Any pathogen |  | 8 | 23 | 25 | 30 | 86 | PR=0.57 (95% CI: 0.28, 1.15) | 0.12 | PR=0.37 (95% CI: 0.16, 0.85) | 0.02 |
| Fuhrmeister 2020 | Any pathogen |  | 75 | 113 | 72 | 116 | 376 | PR=1.04 (95% CI: 0.8, 1.35) | 0.76 | PR=1.05 (95% CI: 0.81, 1.37) | 0.69 |
| Fuhrmeister 2020 | Any pathogen |  | 96 | 266 | 110 | 267 | 739 | PR=0.91 (95% CI: 0.72, 1.15) | 0.43 | PR=0.92 (95% CI: 0.72, 1.16) | 0.47 |
| Boehm 2016 | Any pathogen |  | 16 | 231 | 14 | 232 | 493 | PR=1.14 (95% CI: 0.52, 2.48) | 0.75 | PR=1.13 (95% CI: 0.52, 2.44) | 0.76 |
| Capone 2022 in prep | Any bacteria | Any sample | 7 | 13 | 17 | 20 | 57 | PR=0.76 (95% CI: 0.38, 1.54) | 0.45 | PR=0.6 (95% CI: 0.24, 1.46) | 0.26 |
| Capone 2021 | Any bacteria | Any sample | 28 | 15 | 35 | 10 | 88 | PR=0.84 (95% CI: 0.64, 1.1) | 0.2 | PR=0.85 (95% CI: 0.65, 1.11) | 0.24 |
| Fuhrmeister 2020 | Any bacteria | Any sample | 306 | 144 | 340 | 131 | 921 | PR=0.94 (95% CI: 0.86, 1.03) | 0.18 | PR=0.94 (95% CI: 0.86, 1.02) | 0.14 |
| Reese 2017 | Any bacteria | Any sample | 185 | 792 | 238 | 825 | 2,040 | PR=0.85 (95% CI: 0.66, 1.08) | 0.18 | PR=0.86 (95% CI: 0.68, 1.09) | 0.21 |
| Odagiri 2016 | Any bacteria | Any sample | 8 | 22 | 11 | 19 | 60 | PR=0.73 (95% CI: 0.34, 1.57) | 0.42 |  |  |
| Reese 2017 | Any bacteria | Source water | 68 | 588 | 122 | 747 | 1,525 | PR=0.74 (95% CI: 0.49, 1.12) | 0.15 | PR=0.74 (95% CI: 0.5, 1.12) | 0.16 |
| Odagiri 2016 | Any bacteria | Source water | 8 | 22 | 11 | 19 | 60 | PR=0.73 (95% CI: 0.34, 1.57) | 0.42 |  |  |
| Fuhrmeister 2020 | Any bacteria | Stored water | 138 | 218 | 148 | 237 | 741 | PR=1.01 (95% CI: 0.85, 1.2) | 0.93 | PR=1 (95% CI: 0.84, 1.19) | 0.97 |
| Reese 2017 | Any bacteria | Stored water | 134 | 786 | 147 | 860 | 1,927 | PR=1 (95% CI: 0.75, 1.32) | 0.99 | PR=1.01 (95% CI: 0.77, 1.34) | 0.94 |
| Fuhrmeister 2020 | Any bacteria | House soil | 217 | 144 | 236 | 142 | 739 | PR=0.96 (95% CI: 0.86, 1.08) | 0.53 | PR=0.94 (95% CI: 0.84, 1.06) | 0.31 |
| Capone 2021 | Any bacteria | Latrine soil | 28 | 15 | 35 | 10 | 88 | PR=0.84 (95% CI: 0.64, 1.1) | 0.2 | PR=0.85 (95% CI: 0.65, 1.11) | 0.24 |
| Capone 2022 in prep | Any bacteria |  | 8 | 23 | 21 | 34 | 86 | PR=0.68 (95% CI: 0.32, 1.41) | 0.3 | PR=0.62 (95% CI: 0.28, 1.38) | 0.24 |
| Fuhrmeister 2020 | Any bacteria |  | 64 | 122 | 63 | 124 | 373 | PR=1.02 (95% CI: 0.78, 1.35) | 0.88 | PR=1.02 (95% CI: 0.78, 1.35) | 0.88 |
| Fuhrmeister 2020 | Any bacteria |  | 81 | 281 | 96 | 279 | 737 | PR=0.87 (95% CI: 0.68, 1.13) | 0.3 | PR=0.85 (95% CI: 0.67, 1.09) | 0.2 |
| Capone 2022 in prep | Any virus | Any sample | 0 | 20 | 4 | 33 | 57 | Not estimated |  | Not estimated |  |
| Capone 2021 | Any virus | Any sample | 16 | 27 | 22 | 23 | 88 | PR=0.76 (95% CI: 0.46, 1.25) | 0.28 | PR=0.63 (95% CI: 0.35, 1.14) | 0.13 |
| Fuhrmeister 2020 | Any virus | Any sample | 17 | 330 | 14 | 338 | 699 | PR=1.23 (95% CI: 0.63, 2.4) | 0.54 | PR=1.22 (95% CI: 0.63, 2.34) | 0.56 |
| Boehm 2016 | Any virus | Any sample | 19 | 229 | 15 | 234 | 497 | PR=1.27 (95% CI: 0.6, 2.68) | 0.53 | PR=1.28 (95% CI: 0.62, 2.66) | 0.5 |
| Odagiri 2016 | Any virus | Any sample | 7 | 23 | 10 | 20 | 60 | PR=0.7 (95% CI: 0.3, 1.62) | 0.4 |  |  |
| Odagiri 2016 | Any virus | Source water | 7 | 23 | 10 | 20 | 60 | PR=0.7 (95% CI: 0.3, 1.62) | 0.4 |  |  |
| Boehm 2016 | Any virus | Stored water | 2 | 243 | 1 | 245 | 491 | Not estimated |  | Not estimated |  |
| Boehm 2016 | Any virus | House soil | 5 | 242 | 2 | 247 | 496 | PR=2.52 (95% CI: 0.51, 12.42) | 0.26 | PR=2.52 (95% CI: 0.51, 12.42) | 0.26 |
| Capone 2021 | Any virus | Latrine soil | 16 | 27 | 22 | 23 | 88 | PR=0.76 (95% CI: 0.46, 1.25) | 0.28 | PR=0.63 (95% CI: 0.35, 1.14) | 0.13 |
| Capone 2022 in prep | Any virus |  | 0 | 31 | 5 | 50 | 86 | PR=0 (95% CI: 0, 0) | 0 | PR=0 (95% CI: 0, 0) | 0 |
| Fuhrmeister 2020 | Any virus |  | 7 | 162 | 7 | 161 | 337 | PR=0.99 (95% CI: 0.37, 2.69) | 0.99 | PR=0.99 (95% CI: 0.37, 2.69) | 0.99 |
| Fuhrmeister 2020 | Any virus |  | 11 | 331 | 10 | 332 | 684 | PR=1.1 (95% CI: 0.47, 2.57) | 0.83 | PR=1.06 (95% CI: 0.45, 2.46) | 0.9 |
| Boehm 2016 | Any virus |  | 16 | 231 | 14 | 232 | 493 | PR=1.14 (95% CI: 0.52, 2.48) | 0.75 | PR=1.13 (95% CI: 0.52, 2.44) | 0.76 |
| Capone 2022 in prep | Any protozoa | Any sample | 0 | 20 | 3 | 34 | 57 | Not estimated |  | Not estimated |  |
| Capone 2021 | Any protozoa | Any sample | 15 | 28 | 19 | 26 | 88 | PR=0.83 (95% CI: 0.48, 1.42) | 0.49 | PR=0.83 (95% CI: 0.48, 1.42) | 0.49 |
| Fuhrmeister 2020 | Any protozoa | Any sample | 12 | 293 | 16 | 291 | 612 | PR=0.75 (95% CI: 0.35, 1.65) | 0.48 | PR=0.77 (95% CI: 0.35, 1.67) | 0.5 |
| Capone 2021 | Any protozoa | Latrine soil | 15 | 28 | 19 | 26 | 88 | PR=0.83 (95% CI: 0.48, 1.42) | 0.49 | PR=0.83 (95% CI: 0.48, 1.42) | 0.49 |
| Capone 2022 in prep | Any protozoa |  | 0 | 31 | 4 | 51 | 86 | Not estimated |  | Not estimated |  |
| Fuhrmeister 2020 | Any protozoa |  | 7 | 147 | 8 | 149 | 311 | PR=0.89 (95% CI: 0.33, 2.38) | 0.82 | PR=0.89 (95% CI: 0.33, 2.38) | 0.82 |
| Fuhrmeister 2020 | Any protozoa |  | 5 | 296 | 9 | 292 | 602 | PR=0.56 (95% CI: 0.14, 2.13) | 0.39 | PR=0.56 (95% CI: 0.14, 2.13) | 0.39 |
| Capone 2022 in prep | Any STH | Any sample | 0 | 20 | 3 | 34 | 57 | Not estimated |  | Not estimated |  |
| Capone 2021 | Any STH | Any sample | 20 | 23 | 34 | 11 | 88 | PR=0.62 (95% CI: 0.43, 0.89) | 0.01 | PR=0.69 (95% CI: 0.45, 1.07) | 0.1 |
| Steinbaum 2019 | Any STH | Any sample | 206 | 979 | 173 | 707 | 2,065 | PR=0.88 (95% CI: 0.7, 1.11) | 0.29 | PR=0.87 (95% CI: 0.7, 1.09) | 0.24 |
| Kwong 2021 | Any STH | House soil | 363 | 125 | 687 | 221 | 1,396 | PR=0.98 (95% CI: 0.91, 1.06) | 0.67 | PR=0.98 (95% CI: 0.91, 1.06) | 0.68 |
| Steinbaum 2019 | Any STH | House soil | 209 | 1,000 | 173 | 725 | 2,107 | PR=0.9 (95% CI: 0.72, 1.13) | 0.35 | PR=0.89 (95% CI: 0.71, 1.11) | 0.31 |
| Capone 2021 | Any STH | Latrine soil | 20 | 23 | 34 | 11 | 88 | PR=0.62 (95% CI: 0.43, 0.89) | 0.01 | PR=0.69 (95% CI: 0.45, 1.07) | 0.1 |
| Capone 2022 in prep | Any STH |  | 0 | 31 | 3 | 52 | 86 | Not estimated |  | Not estimated |  |

| **Study** Table S8. Unadjusted and adjusted results by study, sample type, and aggregated variables for MST targets  (any MST, any general MST, any human MST, any animal MST). | **Target** | **Sample** | **Positive, Intervention** | **Negative, Intervention** | **Positive, Control** | **Negative, Control** | **Total observations** | **Unadjusted Prevalence Ratio** | **Unadjusted p-value** | **Adjusted Prevalence Ratio** | **Adjusted p-value** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Capone 2022 in prep | Any MST Marker | Any sample | 20 | 0 | 32 | 5 | 57 | PR=1.16 (95% CI: 1.02, 1.32) | 0.03 | PR=1.16 (95% CI: 1.02, 1.32) | 0.03 |
| Holcomb 2021 | Any MST Marker | Any sample | 41 | 28 | 44 | 17 | 130 | PR=0.82 (95% CI: 0.62, 1.09) | 0.18 | PR=0.86 (95% CI: 0.65, 1.13) | 0.27 |
| Fuhrmeister 2020 | Any MST Marker | Any sample | 421 | 26 | 438 | 29 | 914 | PR=1 (95% CI: 0.97, 1.04) | 0.8 | PR=1.01 (95% CI: 0.97, 1.04) | 0.7 |
| Boehm 2016 | Any MST Marker | Any sample | 220 | 28 | 222 | 27 | 497 | PR=0.99 (95% CI: 0.93, 1.06) | 0.88 | PR=0.99 (95% CI: 0.93, 1.06) | 0.76 |
| Odagiri 2016 | Any MST Marker | Any sample | 30 | 0 | 28 | 2 | 60 | Not estimated |  |  |  |
| Holcomb 2021 | Any MST Marker | Source water | 1 | 21 | 0 | 19 | 41 | Not estimated |  | Not estimated |  |
| Odagiri 2016 | Any MST Marker | Source water | 30 | 0 | 28 | 2 | 60 | Not estimated |  |  |  |
| Holcomb 2021 | Any MST Marker | Stored water | 9 | 39 | 6 | 40 | 94 | PR=1.44 (95% CI: 0.51, 4.08) | 0.5 | PR=1.44 (95% CI: 0.51, 4.08) | 0.5 |
| Fuhrmeister 2020 | Any MST Marker | Stored water | 230 | 119 | 256 | 119 | 724 | PR=0.97 (95% CI: 0.87, 1.07) | 0.52 | PR=0.97 (95% CI: 0.88, 1.08) | 0.63 |
| Boehm 2016 | Any MST Marker | Stored water | 57 | 188 | 82 | 164 | 491 | PR=0.7 (95% CI: 0.51, 0.96) | 0.03 | PR=0.69 (95% CI: 0.5, 0.95) | 0.02 |
| Holcomb 2021 | Any MST Marker | House soil | 21 | 18 | 26 | 18 | 83 | PR=0.91 (95% CI: 0.6, 1.38) | 0.66 | PR=0.89 (95% CI: 0.62, 1.28) | 0.54 |
| Fuhrmeister 2020 | Any MST Marker | House soil | 283 | 38 | 297 | 36 | 654 | PR=0.99 (95% CI: 0.93, 1.05) | 0.7 | PR=0.99 (95% CI: 0.93, 1.05) | 0.66 |
| Boehm 2016 | Any MST Marker | House soil | 180 | 67 | 187 | 62 | 496 | PR=0.97 (95% CI: 0.87, 1.08) | 0.59 | PR=0.97 (95% CI: 0.87, 1.08) | 0.58 |
| Holcomb 2021 | Any MST Marker | Latrine soil | 21 | 9 | 22 | 8 | 60 | PR=0.95 (95% CI: 0.69, 1.32) | 0.78 | PR=0.95 (95% CI: 0.69, 1.32) | 0.78 |
| Capone 2022 in prep | Any MST Marker |  | 27 | 4 | 42 | 13 | 86 | PR=1.14 (95% CI: 0.93, 1.39) | 0.2 | PR=1.14 (95% CI: 0.93, 1.39) | 0.2 |
| Fuhrmeister 2020 | Any MST Marker |  | 174 | 11 | 182 | 1 | 368 | PR=0.95 (95% CI: 0.91, 0.98) | 0.01 | PR=0.95 (95% CI: 0.91, 0.98) | 0.01 |
| Fuhrmeister 2020 | Any MST Marker |  | 346 | 14 | 359 | 9 | 728 | PR=0.99 (95% CI: 0.96, 1.01) | 0.26 | PR=0.99 (95% CI: 0.96, 1.01) | 0.29 |
| Boehm 2016 | Any MST Marker |  | 145 | 102 | 148 | 98 | 493 | PR=0.98 (95% CI: 0.82, 1.16) | 0.78 | PR=0.97 (95% CI: 0.82, 1.15) | 0.74 |
| Capone 2022 in prep | Any human MST Marker | Any sample | 17 | 3 | 30 | 7 | 57 | PR=1.05 (95% CI: 0.82, 1.34) | 0.71 | PR=1.05 (95% CI: 0.82, 1.34) | 0.71 |
| Holcomb 2021 | Any human MST Marker | Any sample | 41 | 28 | 43 | 18 | 130 | PR=0.84 (95% CI: 0.63, 1.12) | 0.24 | PR=0.89 (95% CI: 0.67, 1.18) | 0.41 |
| Fuhrmeister 2020 | Any human MST Marker | Any sample | 124 | 313 | 133 | 330 | 900 | PR=0.99 (95% CI: 0.8, 1.22) | 0.91 | PR=1.01 (95% CI: 0.82, 1.25) | 0.92 |
| Boehm 2016 | Any human MST Marker | Any sample | 26 | 222 | 26 | 223 | 497 | PR=1 (95% CI: 0.57, 1.75) | 0.99 | PR=1 (95% CI: 0.57, 1.76) | 0.99 |
| Odagiri 2016 | Any human MST Marker | Any sample | 22 | 8 | 21 | 9 | 60 | PR=1.05 (95% CI: 0.76, 1.45) | 0.78 |  |  |
| Holcomb 2021 | Any human MST Marker | Source water | 1 | 21 | 0 | 19 | 41 | Not estimated |  | Not estimated |  |
| Odagiri 2016 | Any human MST Marker | Source water | 22 | 8 | 21 | 9 | 60 | PR=1.05 (95% CI: 0.76, 1.45) | 0.78 |  |  |
| Holcomb 2021 | Any human MST Marker | Stored water | 9 | 39 | 5 | 41 | 94 | PR=1.72 (95% CI: 0.57, 5.18) | 0.33 | PR=1.72 (95% CI: 0.57, 5.18) | 0.33 |
| Fuhrmeister 2020 | Any human MST Marker | Stored water | 5 | 310 | 12 | 324 | 651 | PR=0.44 (95% CI: 0.16, 1.23) | 0.12 | PR=0.44 (95% CI: 0.16, 1.23) | 0.12 |
| Boehm 2016 | Any human MST Marker | Stored water | 0 | 245 | 0 | 246 | 491 | Not estimated |  | Not estimated |  |
| Holcomb 2021 | Any human MST Marker | House soil | 20 | 19 | 26 | 18 | 83 | PR=0.87 (95% CI: 0.57, 1.32) | 0.5 | PR=0.86 (95% CI: 0.6, 1.24) | 0.42 |
| Fuhrmeister 2020 | Any human MST Marker | House soil | 68 | 243 | 59 | 261 | 631 | PR=1.19 (95% CI: 0.87, 1.61) | 0.28 | PR=1.24 (95% CI: 0.91, 1.7) | 0.18 |
| Boehm 2016 | Any human MST Marker | House soil | 21 | 226 | 23 | 226 | 496 | PR=0.92 (95% CI: 0.5, 1.71) | 0.79 | PR=0.94 (95% CI: 0.5, 1.75) | 0.84 |
| Holcomb 2021 | Any human MST Marker | Latrine soil | 21 | 9 | 22 | 8 | 60 | PR=0.95 (95% CI: 0.69, 1.32) | 0.78 | PR=0.95 (95% CI: 0.69, 1.32) | 0.78 |
| Capone 2022 in prep | Any human MST Marker |  | 24 | 7 | 38 | 17 | 86 | PR=1.12 (95% CI: 0.83, 1.51) | 0.46 | PR=1.02 (95% CI: 0.75, 1.41) | 0.88 |
| Fuhrmeister 2020 | Any human MST Marker |  | 30 | 142 | 44 | 122 | 338 | PR=0.66 (95% CI: 0.44, 0.99) | 0.04 | PR=0.72 (95% CI: 0.48, 1.07) | 0.11 |
| Fuhrmeister 2020 | Any human MST Marker |  | 58 | 268 | 60 | 265 | 651 | PR=0.96 (95% CI: 0.68, 1.37) | 0.84 | PR=0.96 (95% CI: 0.68, 1.35) | 0.82 |
| Boehm 2016 | Any human MST Marker |  | 7 | 240 | 5 | 241 | 493 | PR=1.39 (95% CI: 0.46, 4.2) | 0.56 | PR=1.39 (95% CI: 0.46, 4.2) | 0.56 |
| Capone 2022 in prep | Any animal MST Marker | Any sample | 12 | 8 | 17 | 20 | 57 | PR=1.31 (95% CI: 0.78, 2.17) | 0.3 | PR=1.2 (95% CI: 0.72, 1.99) | 0.48 |
| Holcomb 2021 | Any animal MST Marker | Any sample | 3 | 66 | 2 | 59 | 130 | PR=1.33 (95% CI: 0.18, 9.59) | 0.78 | PR=1.33 (95% CI: 0.18, 9.59) | 0.78 |
| Fuhrmeister 2020 | Any animal MST Marker | Any sample | 419 | 26 | 437 | 28 | 910 | PR=1 (95% CI: 0.97, 1.04) | 0.91 | PR=1 (95% CI: 0.97, 1.04) | 0.8 |
| Boehm 2016 | Any animal MST Marker | Any sample | 219 | 29 | 221 | 28 | 497 | PR=0.99 (95% CI: 0.93, 1.06) | 0.88 | PR=0.99 (95% CI: 0.93, 1.06) | 0.74 |
| Odagiri 2016 | Any animal MST Marker | Any sample | 28 | 2 | 27 | 3 | 60 | PR=1.04 (95% CI: 0.89, 1.21) | 0.65 |  |  |
| Holcomb 2021 | Any animal MST Marker | Source water | 0 | 22 | 0 | 19 | 41 | Not estimated |  | Not estimated |  |
| Odagiri 2016 | Any animal MST Marker | Source water | 28 | 2 | 27 | 3 | 60 | PR=1.04 (95% CI: 0.89, 1.21) | 0.65 |  |  |
| Holcomb 2021 | Any animal MST Marker | Stored water | 0 | 48 | 1 | 45 | 94 | Not estimated |  | Not estimated |  |
| Fuhrmeister 2020 | Any animal MST Marker | Stored water | 229 | 113 | 253 | 109 | 704 | PR=0.96 (95% CI: 0.86, 1.07) | 0.43 | PR=0.97 (95% CI: 0.87, 1.08) | 0.57 |
| Boehm 2016 | Any animal MST Marker | Stored water | 57 | 188 | 82 | 164 | 491 | PR=0.7 (95% CI: 0.51, 0.96) | 0.03 | PR=0.69 (95% CI: 0.5, 0.95) | 0.02 |
| Holcomb 2021 | Any animal MST Marker | House soil | 2 | 37 | 1 | 43 | 83 | Not estimated |  | Not estimated |  |
| Fuhrmeister 2020 | Any animal MST Marker | House soil | 281 | 30 | 291 | 29 | 631 | PR=0.99 (95% CI: 0.94, 1.05) | 0.82 | PR=0.99 (95% CI: 0.94, 1.04) | 0.72 |
| Boehm 2016 | Any animal MST Marker | House soil | 178 | 69 | 186 | 63 | 496 | PR=0.96 (95% CI: 0.86, 1.08) | 0.53 | PR=0.96 (95% CI: 0.86, 1.08) | 0.51 |
| Holcomb 2021 | Any animal MST Marker | Latrine soil | 2 | 28 | 0 | 30 | 60 | Not estimated |  | Not estimated |  |
| Capone 2022 in prep | Any animal MST Marker |  | 12 | 19 | 18 | 37 | 86 | PR=1.18 (95% CI: 0.7, 2) | 0.53 | PR=1.33 (95% CI: 0.62, 2.86) | 0.47 |
| Fuhrmeister 2020 | Any animal MST Marker |  | 174 | 8 | 182 | 1 | 365 | PR=0.96 (95% CI: 0.93, 1) | 0.03 | PR=0.96 (95% CI: 0.93, 1) | 0.03 |
| Fuhrmeister 2020 | Any animal MST Marker |  | 344 | 15 | 358 | 9 | 726 | PR=0.98 (95% CI: 0.96, 1.01) | 0.17 | PR=0.98 (95% CI: 0.96, 1.01) | 0.19 |
| Boehm 2016 | Any animal MST Marker |  | 144 | 103 | 147 | 99 | 493 | PR=0.98 (95% CI: 0.82, 1.16) | 0.78 | PR=0.97 (95% CI: 0.82, 1.15) | 0.7 |

| **.** Table S9. Baseline covariates by study. Note that Odigari et al. 2016 is not included as data shared from this study were from  village water sources and did not have associated covariates from individual households; therefore all estimates  for this study are unadjusted. | **Boehm 2016** | | **Reese 2017** | | **Steinbaum 2019** | | **Fuhrmeister 2020** | | **Holcomb 2021** | | **Capone 2021** | | **Capone 2022 in prep.** | | **Kwong 2021** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Number of rooms in the household |  | |  | |  | |  | |  | |  | |  | |  |
| Household wealth | |  | |  | |  | |  | |  | |  | |  |  |
| Low | | 125 (25.2%) | | 28 (11.6%) | | 861 (40.9%) | | 153 (25.6%) | | 45 (27.6%) | | 22 (25.0%) | | 14 (24.6%) | 355 (25.4%) |
| Medium-low | | 124 (24.9%) | | 51 (21.1%) | | 439 (20.8%) | | 145 (24.3%) | | 46 (28.2%) | | 23 (26.1%) | | 18 (31.6%) | 343 (24.6%) |
| Medium-high | | 125 (25.2%) | | 39 (16.1%) | | 402 (19.1%) | | 147 (24.6%) | | 35 (21.5%) | | 22 (25.0%) | | 12 (21.1%) | 351 (25.1%) |
| High | | 123 (24.7%) | | 65 (26.9%) | | 403 (19.1%) | | 152 (25.5%) | | 37 (22.7%) | | 21 (23.9%) | | 13 (22.8%) | 347 (24.9%) |
| Missing | | 0 (0%) | | 59 (24.4%) | | 2 (0.1%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | 0 (0%) |
| Number of people in the household | |  | |  | |  | |  | |  | |  | |  |  |
| <5 | | 271 (54.5%) | | 17 (7.0%) | | 612 (29.0%) | | 335 (56.1%) | | 38 (23.3%) | | 0 (0%) | | 0 (0%) | 783 (56.1%) |
| 5-8 | | 199 (40.0%) | | 171 (70.7%) | | 1149 (54.5%) | | 224 (37.5%) | | 44 (27.0%) | | 7 (8.0%) | | 3 (5.3%) | 528 (37.8%) |
| 5-8 | 199 (40.0%) | | 171 (70.7%) | | 1149 (54.5%) | | 224 (37.5%) | | 44 (27.0%) | | 7 (8.0%) | | 3 (5.3%) | | 528 (37.8%) |
| >8 | 27 (5.4%) | | 54 (22.3%) | | 245 (11.6%) | | 38 (6.4%) | | 81 (49.7%) | | 81 (92.0%) | | 54 (94.7%) | | 85 (6.1%) |
| Missing | 0 (0%) | | 0 (0%) | | 101 (4.8%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 0 (0%) |
| Number of rooms in the household |  | |  | |  | |  | |  | |  | |  | |  |
| 1-2 | 0 (0%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 98 (60.1%) | | 61 (69.3%) | | 41 (71.9%) | | 0 (0%) |
| >3 | 0 (0%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 65 (39.9%) | | 27 (30.7%) | | 16 (28.1%) | | 0 (0%) |
| Missing | 497 (100%) | | 242 (100%) | | 2107 (100%) | | 597 (100%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 1396 (100%) |
| Improved roof |  | |  | |  | |  | |  | |  | |  | |  |
| 0 | 8 (1.6%) | | 0 (0%) | | 693 (32.9%) | | 8 (1.3%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 23 (1.6%) |
| 1 | 489 (98.4%) | | 0 (0%) | | 1414 (67.1%) | | 589 (98.7%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 1373 (98.4%) |
| Missing | 0 (0%) | | 242 (100%) | | 0 (0%) | | 0 (0%) | | 163 (100%) | | 88 (100%) | | 57 (100%) | | 0 (0%) |
| Father in agriculture |  | |  | |  | |  | |  | |  | |  | |  |
| 0 | 332 (66.8%) | | 126 (52.1%) | | 0 (0%) | | 419 (70.2%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 952 (68.2%) |
| 1 | 165 (33.2%) | | 89 (36.8%) | | 0 (0%) | | 178 (29.8%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 444 (31.8%) |
| Missing | 0 (0%) | | 27 (11.2%) | | 2107 (100%) | | 0 (0%) | | 163 (100%) | | 88 (100%) | | 57 (100%) | | 0 (0%) |
| Land owned |  | |  | |  | |  | |  | |  | |  | |  |
| 0 | 0 (0%) | | 97 (40.1%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 0 (0%) |
| 1 | 0 (0%) | | 117 (48.3%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 0 (0%) |
| Missing | 497 (100%) | | 28 (11.6%) | | 2107 (100%) | | 597 (100%) | | 163 (100%) | | 88 (100%) | | 57 (100%) | | 1396 (100%) |
| Acres of land owned |  | |  | |  | |  | |  | |  | |  | |  |
| Mean (SD) | 0.110 (0.128) | | Missing | | Missing | | 0.150 (0.206) | | Missing | | Missing | | Missing | | 0.142 (0.212) |
| Median [Min, Max] | 0.0700 [0.0100, 1.23] | | Missing | | Missing | | 0.0800 [0.0100, 2.10] | | Missing | | Missing | | Missing | | 0.0800 [0.0100, 3.15] |
| Missing | 13 (2.6%) | | 242 (100%) | | 2107 (100%) | | 21 (3.5%) | | 163 (100%) | | 88 (100%) | | 57 (100%) | | 62 (4.4%) |
| Maternal education |  | |  | |  | |  | |  | |  | |  | |  |
| No education | 85 (17.1%) | | 0 (0%) | | 0 (0%) | | 86 (14.4%) | | 6 (3.7%) | | 0 (0%) | | 0 (0%) | | 207 (14.8%) |
| Incomplete Primary | 0 (0%) | | 83 (34.3%) | | 1095 (52.0%) | | 0 (0%) | | 38 (23.3%) | | 0 (0%) | | 0 (0%) | | 0 (0%) |
| Primary | 180 (36.2%) | | 30 (12.4%) | | 511 (24.3%) | | 183 (30.7%) | | 14 (8.6%) | | 0 (0%) | | 0 (0%) | | 449 (32.2%) |
| Secondary | 232 (46.7%) | | 70 (28.9%) | | 499 (23.7%) | | 328 (54.9%) | | 41 (25.2%) | | 0 (0%) | | 0 (0%) | | 740 (53.0%) |
| More than secondary | 0 (0%) | | 11 (4.5%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 0 (0%) |
| Missing | 0 (0%) | | 48 (19.8%) | | 2 (0.1%) | | 0 (0%) | | 64 (39.3%) | | 88 (100%) | | 57 (100%) | | 0 (0%) |
| Maternal age |  | |  | |  | |  | |  | |  | |  | |  |
| Mean (SD) | 23.7 (5.18) | | Missing | | 26.4 (6.32) | | 23.7 (5.08) | | Missing | | Missing | | Missing | | 24.0 (5.03) |
| Median [Min, Max] | 23.0 [15.0, 42.0] | | Missing | | 25.5 [14.9, 47.9] | | 23.0 [15.0, 41.0] | | Missing | | Missing | | Missing | | 24.0 [15.0, 43.0] |
| Missing | 0 (0%) | | 242 (100%) | | 11 (0.5%) | | 0 (0%) | | 163 (100%) | | 88 (100%) | | 57 (100%) | | 2 (0.1%) |
| Improved wall |  | |  | |  | |  | |  | |  | |  | |  |
| 0 | 78 (15.7%) | | 0 (0%) | | 2019 (95.8%) | | 197 (33.0%) | | 41 (25.2%) | | 16 (18.2%) | | 10 (17.5%) | | 369 (26.4%) |
| 1 | 419 (84.3%) | | 0 (0%) | | 88 (4.2%) | | 400 (67.0%) | | 122 (74.8%) | | 72 (81.8%) | | 47 (82.5%) | | 1027 (73.6%) |
| Missing | 0 (0%) | | 242 (100%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 0 (0%) |
| Improved floor |  | |  | |  | |  | |  | |  | |  | |  |
| 0 | 461 (92.8%) | | 0 (0%) | | 1999 (94.9%) | | 524 (87.8%) | | 4 (2.5%) | | 1 (1.1%) | | 1 (1.8%) | | 1253 (89.8%) |
| 1 | 36 (7.2%) | | 0 (0%) | | 108 (5.1%) | | 73 (12.2%) | | 159 (97.5%) | | 87 (98.9%) | | 56 (98.2%) | | 143 (10.2%) |
| Missing | 0 (0%) | | 242 (100%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 0 (0%) |
| Electricity |  | |  | |  | |  | |  | |  | |  | |  |
| 0 | 234 (47.1%) | | 34 (14.0%) | | 1958 (92.9%) | | 246 (41.2%) | | 3 (1.8%) | | 4 (4.5%) | | 2 (3.5%) | | 584 (41.8%) |
| 1 | 263 (52.9%) | | 202 (83.5%) | | 147 (7.0%) | | 351 (58.8%) | | 160 (98.2%) | | 84 (95.5%) | | 55 (96.5%) | | 812 (58.2%) |
| Missing | 0 (0%) | | 6 (2.5%) | | 2 (0.1%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 0 (0%) | | 0 (0%) |