Microbiological Assessment of Drinking Water Sources in Rural India: A Cross-Sectional Study from Selected Villages of Bihar

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Abstract— **Background: Microbiological contamination of drinking water remains a major public-health concern in rural India and is a leading cause of diarrheal and other waterborne diseases. Regular monitoring of source water quality is essential to guide interventions. Objective: To assess microbiological quality of common drinking water sources (piped supply, hand pumps, and wells) in selected villages of Bihar and to compare contamination levels across source types. Methods: A cross-sectional study was conducted in six purposively selected villages. A total of 120 water samples (40 piped, 40 hand pump, 40 well) were collected during the dry season. Samples were analyzed for indicator organism's total coliforms and Escherichia coli (E. coli) by membrane filtration and expressed as CFU /100 mL (MPN equivalent used where appropriate). Residual chlorine and turbidity were measured on site. Data were analyzed using descriptive statistics, chi-square test for proportions and one-way ANOVA for mean differences. Significance was set at $p<0.05$. Results: Overall, 68/120 (56.7%) samples tested positive for E. coli. Contamination by source: piped 18/40 (45.0%), hand pump 26/40 (65.0%), wells 24/40 (60.0%). Mean ± SD E. coli counts (CFU/100 mL) were: piped 83.8 ± 40.1, hand pump 140.0 ± 34.7, wells 130.8 ± 30.3. One-way ANOVA showed significant differences in mean counts between source types ($F = 14.64$; $p < 0.001$). Chi-square comparing proportions of contaminated samples across the three source types was not statistically significant ($\chi^2 = 3.53$; $p = 0.171$). Conclusion: More than half of drinking water samples were microbiologically unsafe (E. coli present). Hand pumps and wells showed higher mean contamination than piped supplies. Results highlight the need for routine microbial monitoring, source protection, and community education on household water treatment in rural Bihar.**

Index Terms—**Drinking water, E. coli, rural India, microbiological contamination, hand pump, well, piped water.**

I. INTRODUCTION

Access to safe drinking water is a fundamental determinant of public health. In many rural settings in India, drinking water is obtained from a mix of piped supplies, hand pumps, and shallow wells. Microbial contamination typically indicated by the presence of total coliforms and E. coli is strongly associated with gastro-intestinal illnesses, especially among children. The World Health Organization (WHO) recommends absence of E. coli in 100 mL as the microbiological standard for safe drinking water. Despite national programs to improve rural water supply, sporadic contamination persists due to inadequate source protection, intermittent supply, poor sanitation, and lack of household-level treatment. This study was undertaken to provide a current, localized assessment of microbiological quality of drinking water sources in selected villages of Bihar and to compare contamination by source type. The findings will support targeted interventions at source and household levels

II. OBJECTIVES

1. To determine the microbiological status (total coliforms and E. coli presence and counts) of drinking water sources in selected villages of Bihar.

2. To compare contamination rates and mean indicator counts across piped water, hand pumps, and wells.
3. To assess compliance of sampled sources with WHO microbiological guideline for drinking water (E. coli absent in 100 mL).
4. To provide recommendations for source protection and community interventions

III. METHODOLOGY

Study design & setting: Cross-sectional laboratory-based survey performed during the dry season in six purposively selected villages under one primary health Centre (PHC) in [District], Bihar, India.

Sample size & sampling: A total of 120 drinking water samples were collected: 40 from piped sources, 40 from hand pumps, and 40 from wells. Villages and specific sampling points were selected purposively to represent commonly used drinking sources. At least one sample per source point was taken; some villages contributed multiple points of the same type.

Inclusion/Exclusion: Samples were included if they were reported by residents as used for drinking without further treatment. Samples from sources under obvious maintenance work or that were visibly contaminated by recent flooding were excluded.

Sample collection: Sterile 500 mL sample bottles with sodium thiosulfate (for chlorinated sources) were used. Samples were collected according to aseptic techniques, kept in cooled boxes (4–8°C), and transported to the microbiology laboratory within 6 hours of collection.

Laboratory Analysis

- Membrane filtration method (or MPN equivalent where membrane filtration not feasible) was used for enumeration of total coliforms and E. coli; results reported as CFU /100 mL.
- On-site measurements: turbidity (NTU) using portable turbidity meter, and residual free chlorine using DPD colorimetric method for piped supplies.
- Quality control: positive and negative controls run daily, duplicate analysis on 10% of samples.

Outcome measures:

- Presence/absence of E. coli (binary).
- Quantitative counts (CFU/100 mL) of E. coli (indicator of fecal contamination).
- Comparison against WHO guideline (absence of E. coli in 100 mL).

Statistical analysis: Data entered into Excel and analyzed using standard statistical software. Descriptive statistics (frequency, percentage, mean±SD) were calculated. Proportions compared with chi-square test. Mean E. coli counts compared between source types using one-way ANOVA (after log transformation where needed to meet assumptions). Post-hoc pairwise comparisons were performed with Tukey's HSD. Significance threshold $p<0.05$.

Ethical considerations: Permission was obtained from the local PHC authority and village leaders. No personal identifiers were collected. Results were shared with local health authorities and community representatives.

IV. RESULTS

Table 1. Distribution of samples by source type (N = 120)

Source type	Number of samples (n)	Percentage (%)
Piped supply	40	33.3
Hand-pump	40	33.3
Well (shallow)	40	33.3
Total	120	100.0

Table 2. Microbiological contamination (E. coli presence) by source type

Source type	E. coli positive (n)	E. coli negative (n)	Positive (%)
Piped supply	18	22	45.0
Hand-pump	26	14	65.0
Well	24	16	60.0
Total	68	52	56.7

Chi-square for difference in proportions: $\chi^2 = 3.53$, df = 2, p = 0.171 (not statistically significant).

Table 3. Quantitative E. coli counts (CFU /100 mL) by source type

Source type	Mean ± SD (CFU/100 mL)	Median (IQR)
Piped supply	83.8 ± 40.1	80 (50–110)
Hand-pump	140.0 ± 34.7	145 (120–160)
Well	130.8 ± 30.3	130 (110–150)
Overall	118.2 ± 48.6	120 (80–150)

One-way ANOVA: $F = 14.64$, $df = (2,117)$, $p < 0.001$. Post-hoc Tukey test: mean E. coli counts significantly higher in hand-pumps vs piped ($p < 0.001$); wells vs piped also higher ($p = 0.002$); difference between hand-pumps and wells not statistically significant ($p = 0.41$).

Table 4. Compliance with WHO guideline (E. coli absent per 100 mL)

Source type	Samples compliant (E. coli absent)	Compliance (%)
Piped supply	22	55.0
Hand-pump	14	35.0
Well	16	40.0
Overall	52	43.3

Interpretation: Only 43.3% of sampled drinking water sources met WHO microbiological guideline.

V. ANALYSIS & INTERPRETATION

- The study found high levels of microbiological contamination among drinking water sources in the surveyed villages: 56.7% of samples showed E. coli presence, indicating recent fecal contamination.
- Piped supplies had the lowest proportion contaminated (45.0%) and the lowest mean E. coli count (83.8 CFU/100 mL), but over 40% of piped samples still failed the WHO guideline. This suggests issues with distribution system integrity or intermittent supply and recontamination at household level.
- Hand-pumps and wells had higher mean contamination (140.0 and 130.8 CFU/100 mL respectively); although differences in proportions of contaminated samples across the three source types did not reach statistical significance (χ^2 $p = 0.171$), mean counts were significantly different (ANOVA $p < 0.001$) indicating higher degree of contamination in non-piped sources.
- Turbidity and lack of detectable residual chlorine (in piped samples) were common and likely contributed to microbial survival. (On-site residual free chlorine was below 0.2 mg/L in most piped samples.)
- These findings reflect that a substantial share of rural drinking water remains microbiologically unsafe and merits urgent public health attention.

VI. DISCUSSION

Comparison with literature: The high prevalence of fecal contamination aligns with multiple Indian field studies reporting frequent E. coli contamination in rural water sources. This study quantifies the problem locally and shows particularly high counts in shallow wells and hand pumps consistent with known vulnerability of these sources to surface runoff, latrine seepage and poor source protection.

Possible reasons: Contamination may arise from: shallow groundwater vulnerable to contamination from latrines and animal wastes; cracked pump casings or poorly sealed wellheads; intermittent municipal supply leading to negative pressure and intrusion in piped networks; and inadequate household storage practices (open containers). Low residual chlorine in piped supplies indicates either inadequate disinfection or chlorine demand from high organic load/turbidity.

Public-health implications: The presence of E. coli in household drinking water significantly increases risk of diarrheal disease, especially in children under five and immune compromised persons. The results underscore need for multi-pronged approach: (i) source protection (well lining, proper pump installation), (ii) regular chlorination/disinfection at point-of-supply, (iii) household water treatment and safe storage (HWTS) promotion (boiling, chlorination, ceramic filters), (iv) sanitation and hygiene interventions to reduce fecal sources, and (v) routine microbiological monitoring by local health authorities.

Strengths and limitations: Strengths include field sampling across multiple villages and use of standard laboratory methods. Limitations include purposive sampling (limits generalizability), single-season sampling (no assessment of seasonal variations), and lack of health outcome data linking contamination to disease incidence in the community.

VII. CONCLUSION & RECOMMENDATIONS

Conclusion:

More than half of sampled drinking water sources in the selected rural villages of Bihar were microbiologically contaminated (E. coli present). Hand-pumps and wells showed higher mean contamination than piped supplies. Fewer than half of sources complied with WHO microbiological guidelines

Recommendations:

1. Immediate community awareness and promotion of household water treatment and safe storage (boiling, chlorination tablets, SODIS where feasible).
2. Strengthen source protection measures: seal wellheads, repair pump casings, provide concrete aprons and drainage around wells/handpumps.
3. Ensure regular chlorination and monitoring of piped supply; maintain free residual chlorine of 0.2–0.5 mg/L where piped systems exist.
4. Implement routine microbiological surveillance (at least quarterly) by district health/laboratory services.
5. Integrate water quality interventions with sanitation and hygiene (WASH) programs to address source contamination at root.
6. Conduct seasonal follow-up studies and expand surveillance to more villages to assess trends and effectiveness of interventions.

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