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Microbiological Compliance and Source Protection Gaps in Rural Drinking Water Systems of Camarines Sur, Philippines

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Abstract
Background: Microbiological drinking-water quality and source protection are important concerns in rural upland communities. Baseline assessments can identify water-safety concerns and inform locally appropriate monitoring and community extension activities. Objective: This study evaluated the microbiological quality and documented source-protection conditions of drinking water sources in Barangay Guinaban, Ocampo, Camarines Sur, Philippines, with emphasis on regulatory compliance and implications for local water-safety and extension planning. Methods: A descriptive secondary analysis was conducted using laboratory measurements and field observations documented in a 2026 master's thesis. Total and fecal coliform results from seven identified sampling sites, collected on April 2 and September 9, 2024, were examined against the microbial threshold of <1.1 most probable number (MPN)/100 mL specified in the source document. Results: Six sampling sites had measurements in April and six in September, with five sites represented on both dates. All 12 site-date observations for both total and fecal coliform exceeded the stated threshold. Among the five paired sites, three consistently recorded values exceeding 8.0 MPN/100 mL, while Z4-S1 increased from 4.6 to >8.0 MPN/100 mL and Z7-S1 shifted from 8.0 to >8.0 MPN/100 mL. An inconsistency was identified at the OCS sampling site, which was classified as compliant despite reported September measurements exceeding 1.1 MPN/100 mL. This discrepancy requires verification against the original laboratory certificate. Conclusion: The findings indicate microbiological water-quality concerns across the sampled sources and highlight the need for confirmatory laboratory testing, improved source protection, systematic sanitary inspections, and routine water-quality surveillance. Given the limited sampling periods and censored measurements, the results do not establish seasonal contamination patterns or causal relationships between sanitation conditions and microbial contamination.

Keywords: *Drinking Water Quality; Microbial Contamination; Coliform Bacteria; Rural Water Sources; Water Safety Monitoring.*

I. INTRODUCTION

Safe drinking water depends on both microbial quality and the integrity of source capture, storage, and distribution systems. Total coliform and fecal indicator bacteria have historically been used to screen for conditions that warrant further sanitary investigation. These tests indicate potential microbiological vulnerability rather than identifying a particular pathogen or proving a specific contamination route [1,2].

Rural upland communities may rely on spring catchments and small-scale distribution systems where routine laboratory surveillance and infrastructure maintenance are operational challenges. The World Health Organization recommends water-safety management that combines risk assessment, preventive controls, and verification of drinking water quality [3]. In the Philippines, Department of Health Administrative Order No. 2017-0010 establishes the 2017 Philippine National Standards for Drinking Water (PNSDW) [4]. The precise compliance interpretation depends on the regulated indicator, sampling type, analytical method, and laboratory report.

Barangay Guinaban, Ocampo, Camarines Sur, is an upland community and an adopted community of Mariners' Polytechnic Colleges Foundation of Canaman (Cam Sur), Inc., through its community extension program. It brings together the available drinking-water evidence to identify concerns that can inform the institution's community extension planning. The original graduate thesis combined household questionnaires, field observations and microbiological sampling [5]. The present article reexamines its source-level laboratory results and documented source-protection conditions to inform water-safety planning. Household awareness, toilet facilities and waste-management survey findings remain outside this article's analytical scope.

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Microbiological compliance is an observational property of a sample obtained at a defined location and date, not a permanent designation for the source. Consequently, a source that complies at one monitoring occasion may later exceed a regulatory threshold, while a source exceeding a threshold requires confirmation, investigation, and risk-control action. This distinction is particularly important for small rural supplies with intermittent laboratory access [3,4].

Two analytical distinctions guide this report. First, indicator detection identifies conditions warranting sanitary investigation but does not establish the presence, species, or concentration of particular disease-causing organisms. Second, repeated monitoring can show whether a problem recurs at the same point, but two calendar observations alone cannot separate rainfall, infrastructure condition, sampling variability, and laboratory variation as competing explanations [1–3].

The original thesis also contains household survey and sanitation-management information [5]. To maintain a distinct scientific contribution from a prospective household-level article, the present analysis restricts its primary evidence to water-sampling points, sample dates, recorded indicator levels, and source-protection observations. Household percentages and questionnaire measures are not reanalyzed here.

The objectives were to (i) reconstruct the reported microbiological results by source and date, (ii) compare those values descriptively with the criterion stated in the thesis, (iii) distinguish observed two-date differences from unsupported seasonal inferences, and (iv) identify source-management and monitoring priorities relevant to local stakeholders and Mariners' community extension planning. The article interprets existing evidence; it does not report new laboratory testing or evaluate the effectiveness of an extension intervention.

II. MATERIALS AND METHODS

2.1 Study setting and design. This retrospective descriptive analysis draws on the thesis "Household Sanitation Practices and Drinking Water Quality in Barangay Guinaban, Ocampo, Camarines Sur," submitted in May 2026 [5]. The present article was undertaken because Guinaban is an adopted community of Mariners' Polytechnic Colleges Foundation of Canaman (Cam Sur), Inc. It reexamines existing drinking-water evidence to provide a basis for identifying community needs and planning appropriate extension activities. For the present article, sampling-site codes, dates, bacteriological measurements and narrative source-protection observations were extracted from the thesis's water-quality table and accompanying discussion. No new environmental samples were collected.

2.1.1.Analytical unit and temporal scope. A site-date combination is the observational unit. For each combination, total and fecal coliform are two laboratory endpoints, not two independent sampling units. The study has seven unique coded sites but not seven complete pairs; coverage therefore needs to be described separately from the number of sites.

2.1.2. Measurement context. The thesis reports most-probable-number results in MPN per 100 mL and uses > signs at its upper reported levels [5]. It does not provide sufficient method metadata in the summary table to verify culture medium, incubation conditions, analytical detection range, quality controls, or whether source and distribution samples were drawn after treatment. Accordingly, this manuscript reports those measurements as documented without reconstructing unavailable laboratory procedures.

2.2. Data extraction. Seven site codes appear in the reported laboratory summary: Z2-S1, Z4-S1, Z5-S1, Z7-S1, Z7-S2, Z7-S3, and OCS. Recorded sampling dates are 2 April 2024 (35°C reported in the original heading) and 9 September 2024 (33°C reported). For each site-date combination, total and fecal coliform results were recorded as published, in most probable number per 100 mL (MPN/100 mL). Blank cells were treated as unreported, not as zero or negative findings. The printed laboratory summary does not describe the number of replicate samples, measurement uncertainty, incubation procedure, or exact test kit; consequently, those details are not inferred.

The transcription retained original values and sampling-point identifiers. A comma decimal separator in one thesis cell (4,6) was interpreted typographically as 4.6 for readability, and the inequality signs were preserved. Dashes were treated as missing observations, not as negative results, zero counts, or samples below detection. The original source table is reproduced in compact form in Table 1; no synthetic observations were added.

To audit data completeness, we tabulated the number of monitored sites by date, counted matched monitoring locations across dates, and compared the stated site-level remark with the numerical laboratory columns. This method gives equal weight to the evidence and its limitations and separates raw observations from later interpretations.

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2.3 Compliance classification. The source thesis identifies <1.1 MPN/100 mL as the relevant comparison value for both indicators under PNSDW 2017 [4,5]. Here, results at or above that numerical boundary are marked "above the source-stated threshold," pending comparison with the underlying accredited laboratory report and the exact applicable regulatory provisions. Values such as >8.0 and >1.1 were retained as censored measurements. The labels "FAILED" and "PASSED" printed in the thesis were not substituted for the reported numerical measurements.

2.4 Analysis and limitations. Analyses were restricted to site-date counts, direct comparison with the stated threshold, and qualitative contrasts between the two occasions. No arithmetic means, standard deviations, inferential tests, source rankings, or effect estimates were calculated from censored values. Paired-date interpretation uses only sites with results on both dates. No quantitative source-protection score, rainfall time series, watershed map, or household-to-source exposure linkage was available in the published summary. The use of source measurements alongside contextual observations reflects the general value of complementary quantitative and qualitative evidence discussed by Osma [8], although that study addressed digital trade and the present analysis does not adopt its mixed-method design or inferential procedures.

2.4.1 Handling censored values. An entry such as >8.0 specifies a lower bound rather than an exact count. Treating >8.0 as 8.0 would systematically understate that measurement; assigning an arbitrary value above 8.0 would fabricate precision. The analysis therefore uses exact values where available and ordered categories for visualization. No paired differences, percentage increases, or means were calculated for values reported only as lower bounds.

2.4.2 Interpretation of the two sampling occasions. April and September observations are described by their dates and by the dry/rainy-period descriptions supplied in the thesis. The study does not include a meteorological time series or repeated observations within seasons. Hence, any difference between these two dates is a descriptive temporal contrast, not an estimate of a general seasonal effect.

2.5 Research ethics and provenance. This article reuses environmental measurements previously reported in a graduate thesis, without additional interaction with research participants. The original thesis includes household-level research beyond the scope of the present analysis. Any reuse permissions required by the thesis's intellectual-property notice must be obtained before submission. The author should verify the laboratory report and supply documentary provenance for all extracted observations.

III. RESULTS AND DISCUSSION

3.1 Completeness of laboratory reporting. The thesis table provides six site results in April and six in September. Five site codes (Z2-S1, Z4-S1, Z5-S1, Z7-S1, and Z7-S2) are observed on both dates. Z7-S3 was reported only in April, and OCS only in September. Thus, a comparison involving all seven sources on both dates would not be supported. Table 1 reproduces the analytical measurements while separating them from the contradictory pass/fail remarks in the source thesis.
Table 1. Reported coliform measurements by site and date (MPN/100 mL). Not reported denotes a missing source-table entry; inequality signs reproduce the thesis verbatim.

Site	Apr total	Apr fecal	Sep total	Sep fecal
Z2-S1	>8.0	>8.0	>8.0	>8.0
Z4-S1	4.6	4.6	>8.0	>8.0
Z5-S1	>8.0	>8.0	>8.0	>8.0
Z7-S1	8	8	>8.0	>8.0
Z7-S2	>8.0	>8.0	>8.0	>8.0
Z7-S3	4.6	4.6	Not reported	Not reported
OCS	Not reported	Not reported	>1.1	>1.1

3.1.1. Site-date audit. Six sites have April results (Z2-S1, Z4-S1, Z5-S1, Z7-S1, Z7-S2, and Z7-S3), while six have September results (Z2-S1, Z4-S1, Z5-S1, Z7-S1, Z7-S2, and OCS). These total 12 site-date records, comprising five paired sites and two sites observed at only one date. Because both endpoints are shown for each observed site-date, there are 24 reported indicator entries in the source summary.

On the thesis's own numerical criterion, all 12 observed site-date records are above the stated boundary for both endpoints. However, the source labels OCS as PASSED, making the categorical source designation internally inconsistent. This audit reports numerical screening separately from the historical remark and does not purport to issue a new official compliance certificate.

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3.2. Microbiological measurements. All six reported April site measurements exceeded the thesis's source-stated threshold for both total and fecal coliform. Values were >8.0 MPN/100 mL at Z2-S1, Z5-S1, and Z7-S2; 8 at Z7-S1; and 4.6 at Z4-S1 and Z7-S3. All six reported September site measurements also exceeded the stated threshold: five sites reported >8.0 for both indicators, while OCS reported >1.1. These are measured indicator results, not direct evidence that pathogenic organisms were detected [1,2].

Figure 1. Site-by-date matrix transcribed from the thesis. The displayed value applies to both reported coliform indicators at that site-date. The shading distinguishes available measurements from absent entries, not safe from unsafe results.

Reported total and fecal coliform values (MPN/100 mL)

	2 April 2024	9 September 2024
Z2-S1	>8.0	>8.0
Z4-S1	4.6	>8.0
Z5-S1	>8.0	>8.0
Z7-S1	8	>8.0
Z7-S2	>8.0	>8.0
Z7-S3	4.6	—
OCS	—	>1.1

Both indicators have the same reported value at each shown site-date; — = not reported.

The paired locations can be classified into two descriptive groups. Z2-S1, Z5-S1, and Z7-S2 remained in the same open-ended category (>8.0) on both dates for both indicators. Z4-S1 and Z7-S1 were recorded numerically in April but as >8.0 in September. The latter pattern is consistent with a higher minimum reported level on the second date, although the size of change cannot be measured from censored observations.

Z7-S3 and OCS should never be treated as a temporal pair. Z7-S3 was included only in April and OCS only in September. Combining them into a before-and-after comparison would conflate sampling-point identity with sampling occasion and introduce an unsupported trend. Figure 1 presents the uneven observations explicitly.

3.3. Two-date comparisons. Across five paired sites, Z2-S1, Z5-S1, and Z7-S2 were reported at >8.0 MPN/100 mL for both indicators at both dates. At Z4-S1, reported values changed from 4.6 to >8.0; at Z7-S1, from 8 to >8.0. Because >8.0 is an upper-range expression rather than an exact concentration, the size of the change cannot be estimated reliably. The observations are compatible with differences between two sampling occasions, but they do not establish a seasonal trend. A repeated longitudinal design with rainfall covariates and uncensored or appropriately modeled measurements would be necessary for that inference.

3.4. Reconciliation of the OCS entry. OCS is described in the source narrative as having perimeter fencing and enclosed water tanks and as the sole site that "passed" the standard. Nevertheless, the corresponding September numerical results in the thesis table are >1.1 MPN/100 mL for both indicators, which do not satisfy the same table's stated <1.1 criterion. This internal inconsistency means OCS cannot currently be counted as microbiologically compliant. The original signed laboratory certificate, the exact detection-limit notation, and any laboratory-issued amended report should be checked before publication. The presence of fencing alone cannot validate microbiological safety.

The OCS issue has two dimensions. Numerically, >1.1 MPN/100 mL does not satisfy a threshold expressed as <1.1 MPN/100 mL. Contextually, the original narrative attributes its favorable designation to fencing and an enclosed tank. Both statements can be reproduced as thesis reports, but the recorded microbiological columns cannot establish that fencing resulted in satisfactory bacterial quality. The laboratory sheet, analytical units, transcription, and source-specific records require reconciliation before making such a claim.

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This discrepancy is substantively important, not merely editorial. If operational decisions rely on the word PASSED while microbiological columns suggest an exceedance, protective measures may be delayed. A defensible surveillance register should maintain the original numeric observations, the applicable regulatory decision rule, the laboratory interpretation, and the final management decision as separate auditable fields.

3.5. Source protection and operational implications. The original account describes limited water-treatment infrastructure and different source-protection conditions [5]. The documented coliform signals warrant immediate sanitary inspection of spring intakes, storage-tank seals, animal access routes, drainage, upstream waste sources, and the distribution network. These are candidate investigation targets rather than empirically confirmed causes at particular sites. Preventive risk management should combine repeat microbiological tests with on-site sanitary surveys and documented corrective actions [3,4]. Well-documented broader concerns about faecal exposure and aquifer degradation provide the context for these precautionary inspections [6,7].

3.5.1. Plausible exposure pathways. Where spring boxes or storage structures are inadequately sealed, surface water, animal activity, and disturbed soil may provide routes for microbial material to reach a water supply. The thesis discusses these vulnerabilities based on site observations [5]. Its summary, however, contains no quantified sanitary-risk score, source-to-contamination distance measurement, or pathogen-source tracking. These pathways are hypotheses for follow-up investigation, not proven causal explanations for the reported MPN values.

3.5.2. Operational interpretation. Source fencing and tank enclosures may be useful physical protection measures, but they do not substitute for microbial monitoring, sanitary inspection, cleaning and maintenance, or effective treatment where required. A management program should integrate infrastructure inspection with appropriately documented laboratory results and clear communication to users [3,4]. In Guinaban, the adopted-community partnership provides a basis for Mariners' research and community extension personnel to coordinate with barangay officials, water-system operators and the appropriate local health offices. Potential institutional contributions include community education, participatory identification of source-protection concerns, support for monitoring records and facilitation of referrals for accredited testing. Responsibilities for testing, treatment and corrective action should be agreed with the competent service providers. These are proposed uses of the baseline, rather than activities whose effectiveness was measured in this study.

3.6. Implications for monitoring design. A practical surveillance protocol would assign a stable identifier to each source, preserve sampling coordinates and chain-of-custody records, state test method and reporting limits, document rainfall antecedents, repeat sampling across multiple months, and report confirmatory results after remediation. Detecting a microbiological indicator should trigger risk response appropriate to local public-health guidance rather than assumptions about specific infection outcomes. A future investigation could test whether source protections are associated with improved quality, but the present records do not estimate that relationship.

3.6.1 Proposed monitoring workflow. Figure 2 provides a practical decision sequence based on the audit findings, rather than a tested intervention. Each field sampling event should link a unique site ID to date/time, source type, nearby sanitation hazards, sampling conditions, analytical method, numerical result and laboratory sign-off. If results exceed the applicable limit or conflict with a textual interpretation, the record should be flagged for confirmation and urgent risk assessment before the source is described as safe.

3.6.2 Recommended record structure. A monitoring register should include a stable site identifier, coordinates, sampling date and time, source type, sampling point relative to treatment, both coliform results, analytical method and reporting limits, applicable decision criterion, laboratory interpretation, observed protection structures and sanitary hazards, sample collector, testing laboratory, corrective actions and follow-up results. Recording these fields separately supports comparison across future monitoring occasions and reduces the risk of treating source-level remarks as substitutes for laboratory evidence.

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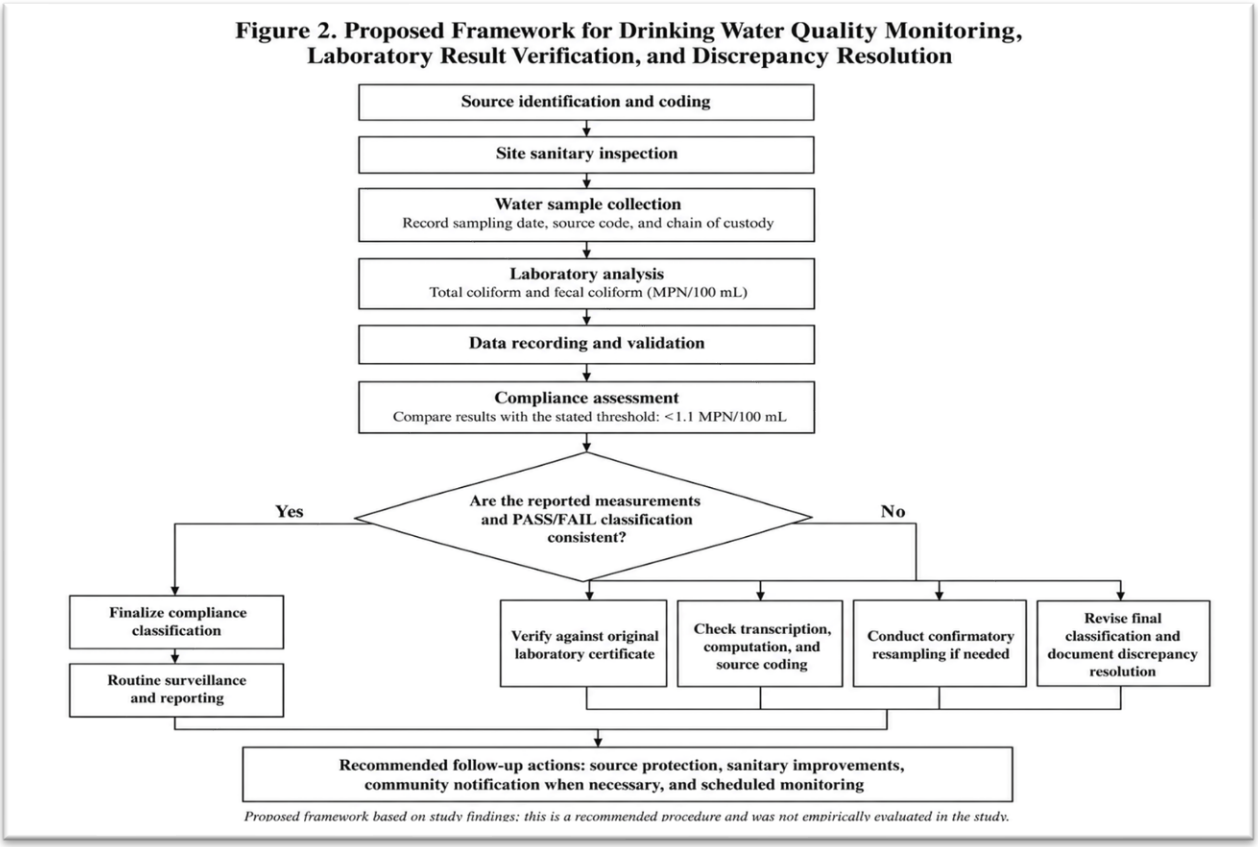

Only two sampling dates are available, and the reported water temperatures in the thesis header cannot substitute for rainfall, flow, or water-chemistry observations. No individual laboratory replicates, field blanks, confidence intervals, or independent retest records are available in the extracted table. These limitations preclude estimation of variability, statistical seasonal effects or the relative effectiveness of particular engineering controls.

No direct evidence links a particular household sanitation practice to contamination at a particular sampling point in the present source-level data. The analysis also cannot establish whether a measured concentration reflects raw spring water, storage-tank water, or water delivered to consumers unless the full sampling log is inspected. Conclusions must therefore remain specific to the documented water samples rather than to every household tap or all municipal supplies.

Finally, the thesis reports its own compliance cutoff and uses the categories total and fecal coliform. This report does not independently certify that every analytical endpoint and threshold corresponds to the complete regulatory testing requirements applicable to each source type. Final regulatory determinations should be made using the original laboratory certificates and the operative DOH requirements [4].

3.7 Study limitations. The analysis uses reported rather than independently re-tested laboratory measurements. It includes only two time points, uneven site coverage, right-censored coliform results, limited procedural metadata, and no concurrent site-specific rainfall data. The original record's OCS pass/fail inconsistency remains unresolved. These limitations constrain claims about seasonal change, source-to-source differences, sanitary risk factors, and potential health outcomes.

IV. CONCLUSION

The reported laboratory summary identifies coliform results above the source thesis's stated drinking-water criterion at every observed site-date combination. The five paired monitoring points show repeated exceedances of the source-stated criterion, with some higher lower-bound readings at the second sampling occasion, although censoring and the sparse design preclude estimation of seasonal effects. A critical discrepancy between the OCS numerical result and its "PASSED" label prevents any claim of verified compliance at that point. Confirmatory accredited testing, reconciliation of laboratory records, sanitary inspection, and structured recurring surveillance are necessary before source safety and management effectiveness can be assessed. This article is a discrete reanalysis of source-level microbial evidence from Bulawan's graduate thesis; its household sanitation survey is not analyzed here.

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The study supports a source-specific surveillance response: preserve quantitative laboratory records, resolve the OCS classification contradiction, complete the missing site-date observations, and document source sanitary inspections alongside follow-up tests. These actions can be undertaken without assuming that the observed two-date differences demonstrate a general rainy-season effect or establish the causal origin of contamination. As Guinaban is an adopted community of Mariners' Polytechnic Colleges Foundation of Canaman (Cam Sur), Inc., the findings can inform jointly prioritized extension activities and coordination with local water and health authorities. Guinaban's adopted-community relationship with Mariners provided the rationale for preparing this article and interpreting the available evidence for community extension planning. The available data do not demonstrate improvements attributable to that partnership.

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Conflict of Interest
The author declares no conflict of interest.

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