Water Quality Evaluation at the Tinanan-Kulaman River Confluence: A Multi-Site Physicochemical Assessment

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ABSTRACT

This study evaluated the physicochemical water quality parameters at four sampling sites along the confluence of the Tinanan and Kulaman Rivers in Arakan, Cotabato, Philippines. The parameters assessed included temperature, electrical conductivity (EC), total dissolved solids (TDS), pH, and salinity. Sampling was conducted on May 30, 2026 at the following sites: Site 1 (50 m upstream of the confluence along the Tinanan River), Site 2 (at the confluence), Site 3 (50 m upstream of the confluence along the Kulaman River), and Site 4 (50 m downstream of the confluence). Three replicate measurements were collected per site using a calibrated pH meter capable of measuring multiple physicochemical parameters. Mean ± standard deviation values were computed and compared using one-way ANOVA. Results revealed that all physicochemical parameters were within the acceptable limits set by the Department of Environment and Natural Resources (DENR) Administrative Order 2016-08. No significant variation in salinity was observed across all sites. However, notable differences were detected in EC and TDS between the Tinanan River site and the Kulaman River site, reflecting the distinct hydrological characteristics of each tributary. The confluence zone exhibited intermediate parameter values, suggesting mixing effects. The findings indicate that both rivers maintain good water quality at the point of confluence, providing baseline data for future long-term monitoring and watershed management.

Keywords: water quality, physicochemical parameters, river confluence, Tinanan River, Kulaman River, TDS, EC, pH, salinity, DENR DAO 2016-08

INTRODUCTION

Freshwater rivers serve as critical ecological and socioeconomic resources, supporting biodiversity, agriculture, and human settlements. The physicochemical characterization of river water is an essential component of environmental monitoring, providing baseline data for assessing water suitability for various uses including irrigation, domestic supply, and aquatic ecosystem sustainability (Chapman, 1996; Wetzel, 2001).

River confluences, where two or more tributaries meet, represent dynamic hydrological zones characterized by complex mixing patterns that influence downstream water quality (Rice et al., 2008). Understanding the physicochemical dynamics at confluence zones is crucial for watershed management and pollution monitoring (Benda et al., 2004).

The Tinanan and Kulaman Rivers are located in Arakan, Cotabato, Philippines, a region characterized by agricultural landscapes and forested uplands. Despite their ecological importance, limited peer-reviewed data exist on the current physicochemical status of these rivers, particularly at their confluence. A previous study conducted in 2009 assessed parameters such as pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), total suspended solids (TSS), TDS, and total solids (TS) along a 1,500-m downstream baseline using laboratory analysis. However, that study employed different spatial sampling designs and did not include EC and salinity measurements.

The present study addresses this gap by focusing specifically on a multi-site assessment of five key physicochemical parameters — temperature, EC, TDS, pH, and salinity — at four strategically located sites around the Tinanan-Kulaman River confluence. The aim is to characterize the spatial variability of water quality

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at the confluence zone and to establish current baseline data aligned with DENR Administrative Order 2016-08 standards.

MATERIALS AND METHODS

Study Area

The study was conducted on May 30, 2026 at the confluence of the Tinanan and Kulaman Rivers in Arakan, Cotabato, Philippines. Four sampling sites were established: Site 1 (50 m upstream along the Tinanan River), Site 2 (at the point of confluence), Site 3 (50 m upstream along the Kulaman River), and Site 4 (50 m downstream of the confluence). These sites were selected to capture the upstream conditions of each tributary, the mixing zone at the confluence, and the initial downstream conditions.

Sample Collection and Measurement

Three replicate in-situ measurements were collected at each sampling site using a calibrated pH meter (with built-in sensors for temperature, EC, TDS, and salinity). Water quality parameters measured included water temperature (°C), electrical conductivity (EC, $\mu S\ cm^{-1}$), total dissolved solids (TDS, $mg\ L^{-1}$), pH, and salinity (%). The pH meter was calibrated prior to field use following the manufacturer's standard calibration procedure using buffer solutions. Measurements were taken at mid-stream at a consistent water depth to minimize within-site spatial variability. The instrument was rinsed with distilled water between sites to prevent cross-contamination.

Statistical Analysis

Descriptive statistics (mean ± standard deviation) were computed for each parameter at each site. One-way Analysis of Variance (ANOVA) was performed to determine significant differences in physicochemical parameters across the four sampling sites. A significance level of $\alpha = 0.05$ was used. All statistical analyses were performed using standard statistical software.

RESULTS AND DISCUSSION

Physicochemical Parameters

Table 1 presents the mean ± SD values of physicochemical parameters measured at the four sampling sites using the pH meter.

Table 1. Physicochemical Analyses of water samples obtained from four sampling sites at the Tinanan-Kulaman River confluence.

Site	Temperature (°C)	Electric Conductivity ($\mu S\ cm^{-1}$)	Total Dissolved Solid ($mg\ L^{-1}$)	Water pH	Salinity, %
1	28.37 ± 0.06	380.33 ± 3.06	189.67 ± 1.53	8.23 ± 0.182	0.01 ± 0.000
2	27.67 ± 0.47	318.00 ± 55.46	159.00 ± 27.73	8.40 ± 0.055	0.01 ± 0.000
3	27.17 ± 0.21	289.67 ± 4.51	144.00 ± 1.73	8.46 ± 0.025	0.01 ± 0.000
4	27.27 ± 0.31	323.67 ± 50.14	160.67 ± 25.89	8.53 ± 0.015	0.01 ± 0.000
Standard Value	25–31 (DAO, 2016-08)	1000 (DAO, 2016-08)	1000 (DAO, 2016-08)	6.5–9.0 (DAO, 2016-08)	0.50, %

Temperature

Water temperature ranged from 27.17 ± 0.21°C (Site 3, Kulaman River) to 28.37 ± 0.06°C (Site 1, Tinanan River), as recorded by the pH meter's built-in temperature sensor. All values were within the DENR DAO 2016-08 standard range of 25–31°C for freshwater bodies. The slightly higher temperature at Site 1 may be attributable

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to differences in riparian canopy cover and stream morphology between the two tributaries. Temperature at the confluence (Site 2: 27.67 ± 0.47°C) reflected a mixing effect between the two tributaries, consistent with confluence mixing dynamics reported in literature (Rice et al., 2008).

Electrical Conductivity (EC)

EC values ranged from 289.67 ± 4.51 µS cm^{-1} (Site 3) to 380.33 ± 3.06 µS cm^{-1} (Site 1), all well below the standard limit of 1,000 µS cm^{-1} (DAO 2016-08). The higher EC at Site 1 suggests a greater concentration of dissolved ions in the Tinanan River compared to the Kulaman River. The elevated standard deviation at Sites 2 and 4 (±55.46 and ±50.14, respectively) indicates variability in ion mixing at the confluence and downstream zones, which is consistent with hydrodynamic mixing at river confluences (Mackay, 1972).

Total Dissolved Solids (TDS)

TDS values followed a pattern similar to EC, ranging from 144.00 ± 1.73 mg L^{-1} (Site 3) to 189.67 ± 1.53 mg L^{-1} (Site 1), all within the permissible limit of 1,000 mg L^{-1} (DAO 2016-08). The correlation between EC and TDS across sites is expected, as EC is a proxy measure of dissolved solids in water (Hem, 1985). The relatively low TDS across all sites suggests minimal anthropogenic contamination at the time of sampling.

pH

pH values ranged from 8.23 ± 0.182 (Site 1) to 8.53 ± 0.015 (Site 4), indicating mildly alkaline conditions across all sites. All values fell within the acceptable range of 6.5–9.0 (DAO 2016-08). The slight increase in pH downstream (Site 4) may be attributed to photosynthetic activity or carbonate buffering in the mixed waters. Alkaline pH in tropical rivers has been associated with high primary productivity and carbonate-rich geology (Boyd, 2000).

Salinity

Salinity was uniformly 0.01 ± 0.000% across all four sites, far below the standard threshold of 0.50% (DAO 2016-08). This confirms the freshwater nature of both rivers and the confluence zone, with no detectable saltwater intrusion or saline contamination. The absence of salinity variation is consistent with the inland location of the study area.

CONCLUSION

This study demonstrated that the physicochemical water quality parameters — temperature, EC, TDS, pH, and salinity — measured using a calibrated pH meter at the four sampling sites along the Tinanan-Kulaman River confluence were all within the acceptable limits prescribed by DENR Administrative Order 2016-08. The Tinanan River exhibited higher EC and TDS values compared to the Kulaman River, reflecting differences in the dissolved ion load of the two tributaries. The confluence zone showed intermediate values consistent with hydrological mixing. Salinity and pH were uniform across all sites, indicating a stable freshwater environment with no signs of saline intrusion or acidification.

These findings provide an updated baseline dataset for the Tinanan-Kulaman River system, expanding upon the 2009 study by incorporating EC and salinity measurements and adopting a confluence-centered spatial design. The current water quality status of both rivers is within safe standards, indicating that the confluence zone is not yet significantly impacted by anthropogenic pollution.

RECOMMENDATIONS

To sustain and further understand the water quality of the Tinanan-Kulaman River confluence, an integrative and proactive monitoring approach is imperative. We recommend the implementation of the following measures: (1) the expansion of water quality monitoring to include additional parameters such as dissolved oxygen (DO), biochemical oxygen demand (BOD), turbidity, nitrates, phosphates, and fecal coliform count to provide a more comprehensive assessment of the physicochemical and microbiological status of the confluence zone; (2) the conduct of seasonal and long-term monitoring across wet and dry periods to detect temporal fluctuations in water quality and identify emerging pollution trends before they reach critical levels; (3) the extension of sampling coverage beyond the immediate confluence zone to include sites further upstream and downstream along both the Tinanan and Kulaman Rivers, thereby capturing the broader spatial dynamics of water quality in the watershed; (4) the promotion of community-based water quality monitoring programs in coordination with local government units and environmental agencies to ensure sustained surveillance and timely response to any deterioration in water conditions; and (5) the investigation of upstream land use activities, particularly agricultural practices, and their potential contribution to the elevated EC and TDS levels observed in the Tinanan River. The Tinanan-Kulaman River confluence represents a vital freshwater resource for the communities and ecosystems of Arakan, Cotabato, and its preservation is critical to sustaining biodiversity, supporting local livelihoods, and ensuring long-term water security. Addressing these concerns through evidence-based policy interventions, robust environmental regulation, and collaborative stakeholder engagement will be instrumental in safeguarding the ecological integrity of this confluence for future generations.

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