Physicochemical Characterization and Screening-Level Treatability Assessment of Institutional Wastewater: A Case Study of Far Western University, Nepal

Sagar Hamal[1*], Shravya Raj Pandit[1]
[1]School of Engineering, Far Western University, Kanchanpur, Nepal
*Corresponding Author, Email: hamal.sagar@fwu.edu.np

Abstract

Wastewater produced by educational institutions in low-resource contexts is commonly discharged without treatment, despite the limited availability of empirical evidence describing its composition and treatment potential. In response to this gap, the present study undertakes a physicochemical characterization and a screening-level assessment of the treatability of wastewater generated at the central campus of Far Western University (FWU), Nepal. Grab samples were collected during peak usage periods in the pre-monsoon season from three representative sources: toilet and bathing facilities, canteen activities, and laboratory discharges. Key parameters including pH, total suspended solids (TSS), five-day biochemical oxygen demand (BOD_5), and chemical oxygen demand (COD) were determined in accordance with standard APHA analytical protocols. Wastewater exhibited mildly alkaline conditions, with a mean pH of 8.3 ± 0.63. Average concentrations of TSS (140 ± 35 mg/L), BOD_5 (213 ± 24 mg/L), and COD (453 ± 37 mg/L) substantially exceeded applicable effluent discharge limits, reflecting a high load of suspended solids and biodegradable organic matter. The mean BOD_5/COD ratio of 0.46 ± 0.03 indicates moderate biodegradability and suggests suitability for biological treatment processes, while the TSS/BOD_5 ratio of 0.64 ± 0.08 implies favorable settling behavior and effective potential for primary solids removal. These indicators were interpreted conservatively, acknowledging the inherent limitations associated with single-event grab sampling. Findings indicate that wastewater generated at FWU is predominantly domestic in character but exhibits elevated suspended solids and organic strength. This composition supports a treatment approach involving preliminary and primary solids removal followed by biological processes. While the study provides baseline evidence for an underrepresented institutional setting in western Nepal, extended temporal monitoring, composite sampling, and pilot-scale evaluations are necessary to confirm treatment performance and refine system design parameters.

Keywords: *Physicochemical, BOD, COD, Preliminary Wastewater Treatment, Biological Wastewater Treatment*

Introduction

Wastewater is characterized by its physical, chemical, and biological properties, and the selection of appropriate treatment processes—physical, chemical, and/or biological—depends fundamentally on pollutant loading and applicable regulatory requirements (Abdalla & Hammam, 2014). In institutional settings, wastewater typically originates from domestic-type sources such as toilets, bathrooms, dormitories, cafeterias, and administrative facilities. University campuses, however, constitute a distinct class of institutional generators because laboratory facilities and workshops can contribute effluents that differ from conventional domestic sewage. These additional inputs arise from diverse activities, chemical reagents, and intermittent discharges, yielding mixed wastewater streams with higher variability and complexity (Desye et al., 2022; Ruslinda et al., 2024; Ufitinema et al., 2025). While domestic wastewater is generally highly biodegradable, laboratory and workshop effluents may exhibit industrial-like characteristics, including inert or potentially toxic constituents that can constrain conventional biological treatment (Dahamsheh & Wedyan, 2017; Ufitinema et al., 2025).

Globally, more than 80% of generated wastewater is discharged without adequate treatment, with the burden disproportionately concentrated in low- and middle-income countries lacking centralized sewerage infrastructure (UNESCO, 2017). In decentralized contexts, medium-scale wastewater generators such as universities frequently operate outside formal collection and regulatory frameworks, resulting in localized discharge of untreated or partially treated effluents into nearby surface water bodies (UN-WWAP, 2017). These challenges are particularly acute in South Asia, where rapid institutional expansion has not been matched by wastewater treatment capacity or enforcement mechanisms (Pottinger-Glass et al., 2025).

In Nepal, assessments of water governance similarly highlight persistent constraints in financial, technical, and human resources at the local government level, limiting the effective monitoring and enforcement of wastewater management regulations (Gupta, 2023). Consequently, institutional effluents often remain unmanaged under weak oversight, elevating localized environmental and public health risks within already stressed catchments (Desye et al., 2022; Ufitinema et al., 2025). National estimates indicate that only about 30% of domestic sewage is safely treated (UN Water Nepal, 2024). In Kathmandu Valley, many wastewater treatment plants operate below capacity or remain partially dysfunctional, resulting in treatment of only approximately 5% of urban wastewater prior to discharge (Jha & Bajracharya, 2014). Kathmandu alone generates an estimated 99.5 million liters per day of sewage and industrial effluent, nearly 75% of which is discharged untreated into adjacent rivers and streams (Thapa, 2020). Conditions outside the capital are markedly worse. A sanitation survey conducted in Sudurpaschim Province reported that nearly half of fecal sludge remained uncontained and that only 1% of wastewater received any form of treatment, noting the absence of a single wastewater treatment plant in the province (ENPHO & MuAN, 2023). As a result, wastewater governance and monitoring remain heavily urban-centric, leaving substantial information gaps regarding institutional wastewater in provincial regions of Nepal, where field-based campus wastewater data are scarce and evidence from western Nepal is virtually absent from the literature.

A prerequisite for defensible wastewater management is systematic characterization of influent quality prior to process selection and design (Sahota & Pandove, 2010). In data-limited institutional settings, screening-level indicators derived from basic physicochemical parameters are commonly employed to support early decision-making. The biochemical oxygen demand to chemical oxygen demand ratio (BOD_5/COD) is used to approximate organic biodegradability, while the total suspended solids to BOD_5 ratio (TSS/BOD_5) provides a first-order indication of solids characteristics relevant to upstream removal. These indicators do not demonstrate treatment performance or removal efficiencies; rather, they provide preliminary feasibility insights and must be complemented by temporal monitoring and, where feasible, pilot-scale testing or process validation (Jones et al., 2021; Samudro & Mangkoedihardjo, 2010).

Far Western University (FWU) Central Campus, located in Bhimdatta Municipality of Sudurpaschim Province, is undergoing institutional expansion but lacks a dedicated wastewater treatment system. Wastewater is currently managed through septic tanks or soak pits, or discharged untreated into the surrounding environment, posing a potential risk of localized pollution on and around the campus. To support evidence-based wastewater planning in this understudied regional context, the present study aimed to establish baseline physicochemical characteristics of wastewater generated from major functional units of the FWU central campus.

Objectives

Specifically, the study objectives were to:

(1) quantify key physicochemical parameters (pH, TSS, BOD_5, and COD) across representative campus wastewater sources; and
(2) screening-level assessment of biodegradability and solids characteristics using BOD_5/COD and TSS/BOD_5 ratios to provide early consideration of physical and biological treatment options.

Literature Review

Characteristics of Institutional Wastewater

Physicochemical indicators such as BOD_5, COD, and TSS are widely used to quantify pollutant loading and support preliminary assessment of wastewater streams (Dahamsheh & Wedyan, 2017; Grimah et al., 2024; Novita et al., 2022). BOD_5 represents the oxygen demand exerted by biodegradable organic matter during microbial oxidation over five days at 20 °C, and is commonly used as an indicator of organic pollution. In untreated domestic wastewater, BOD_5 typically range between 100 and 300 mg/L. COD measures the total oxygen equivalent required for chemical oxidation of both biodegradable and non-biodegradable organic and inorganic substances (Abdalla &

Hammam, 2014; Dahamsheh & Wedyan, 2017). Together, BOD_5 and COD characterize organic strength, with COD often exceeding BOD_5 by a factor of two to four in untreated domestic wastewater. TSS reflects suspended organic and inorganic particles, including fecal matter, sludge, silt, or algae, and values in municipal influent often range from 100 to 500 mg/L, with higher concentrations occurring when high-solids sources are present (Qasem, 2024).

Wastewater generated by university campuses frequently deviates from typical domestic ranges due to high user density and the presence of additional sources such as cafeterias, laundries, and laboratories, which increase variability and may elevate pollutant loads. A Moroccan university campus, for example, reported average COD concentrations of approximately 967–1150 mg/L, BOD_5 of 70–119 mg/L, and TSS values reaching 1660 mg/L, reflecting a heterogeneous, high-load effluent with low biodegradability indices (BOD_5/COD ≈ 0.1–0.2) that necessitated strong pre-treatment (Grimah et al., 2024). pH is also a critical parameter, as most biological treatment processes and receiving ecosystems function optimally within a near-neutral range of approximately 6–9 (Qasem, 2024). Although many institutional wastewaters fall within this range, extreme values may occur due to laboratory discharges. An Indonesian university survey reported pH values ranging from 2.3 to 9.7, alongside TSS concentrations of 130–580 mg/L, BOD_5 of 108–507 mg/L, and COD of 163–1428 mg/L, underscoring substantial intra-campus variability (Ruslinda et al., 2024).

Comparable variability has been documented across diverse institutional settings. Academic wastewater in Rwanda exhibited average COD concentrations of approximately 715 mg/L (Ufitinema et al., 2025), while another campus study reported COD of 315–366 mg/L, BOD_5 of 231–329 mg/L, and TSS frequently exceeding 200 mg/L (Dahamsheh & Wedyan, 2017). Evaluations of campus treatment systems further indicate that partial reductions are achievable, such as pond-based treatment achieving up to 56% COD and 75% BOD_5 removal in an Ethiopian university context (Desye et al., 2022). Nevertheless, untreated campus wastewater often exceeds regulatory thresholds, particularly when laboratory sources contribute constituents such as heavy metals or other hazardous compounds (Novita et al., 2022; Dahamsheh & Wedyan, 2017). Collectively, this evidence underscores the necessity of influent characterization as a prerequisite for defensible process selection in institutional wastewater systems.

Screening-Level Treatability Indicators

Given the compositional complexity of institutional wastewater, screening-level ratios are commonly applied to support preliminary treatability inference. The BOD_5/COD ratio, often referred to as a biodegradability index, indicates the proportion of organic matter that is readily biodegradable. Although no universally fixed thresholds exist, municipal raw wastewater typically exhibits BOD_5/COD values between 0.4 and 0.8, whereas lower ratios indicate increasing contributions of non-biodegradable or inhibitory compounds (Abdalla & Hammam, 2014). Ratios above 0.4 generally suggest favorable conditions for biological treatment, values between 0.3 and 0.4 indicate moderate biodegradability that may require longer retention times or microbial acclimation, and ratios below 0.3 imply limited biodegradability and a likely need for physical or chemical pre-treatment (Abdalla & Hammam, 2014; Herrera et al., 2024).

The TSS/BOD_5 ratio provides complementary insight into solids behavior relative to biodegradable organic loading. Untreated sewage typically exhibits a TSS/BOD_5 ratio near unity, whereas substantially higher ratios (>2–3) suggest dominance of particulate solids, commonly associated with algal proliferation or resuspended sludge. An effluent TSS/BOD_5 ratio exceeding 2 can therefore signal solids-related operational challenges such as poor settling or algal contamination, while ratios around approximately 1.5 are indicative of normal lagoon performance and can help distinguish whether solids removal or aerobic digestion should be prioritized (Hill, 2022; USEPA, 2022).

Empirical studies demonstrate the utility of these ratios as preliminary decision-support tools. A year-round survey across academic sites in Rwanda reported substantial variability in COD concentrations, highlighting that academic wastewater can be highly polluted with organic matter and nutrients (Ufitinema et al., 2025). Indonesian studies applied BOD_5/COD ratios of 0.3–0.4 to classify campus wastewater as moderately biodegradable for management planning purposes (Novita et al., 2022). Although many published studies emphasize treatment performance evaluation, such as pond or wetland systems (Desye et al., 2022; Ufitinema et al., 2025), baseline characterization remains limited, particularly outside major urban centers. In Nepal, wastewater research is predominantly concentrated on urban domestic systems (Jha & Bajracharya, 2014; Thapa, 2020), and published evidence on campus wastewater in western Nepal is lacking. In such data-poor contexts, screening-level ratios derived from grab-sample analyses can still provide a defensible initial triage for assessing whether conventional biological treatment is plausible or whether pre-treatment is likely required, while explicitly acknowledging that these indicators cannot identify toxicants or confirm treatment performance (Bhattacharjee, 2017). Without localized characterization, wastewater planning remains speculative and risks failure through underestimation of pollutant loads or overestimation of biodegradability (Novita et al., 2022).

Methodology

Study Area and Wastewater Sources

The investigation was carried out at the central campus of Far Western University (FWU), situated in Bhimdatta Municipality, Kanchanpur District, Sudurpaschim Province, Nepal (28°57′20″ N, 80°10′39″ E; elevation 234.6 m above mean sea level). Established in 2010 and operational since 2011, the campus comprises academic and administrative buildings, laboratory facilities, and food service units. Wastewater generated across the campus is managed through decentralized on-site systems, predominantly septic tanks and soak pits, as no centralized wastewater treatment infrastructure is currently in operation.

During the pre-monsoon study period (April 2024), the campus supported approximately 5,012 students and staff, making it representative of medium-scale institutional wastewater generation in emerging provincial urban centers of western Nepal. To capture the principal functional wastewater streams contributing to the overall campus effluent, three representative discharge points were selected: wastewater from toilets and bathrooms (WW1), canteen wastewater (WW2), and laboratory wastewater (WW3). Together, these sources reflect sanitary, food service, and intermittent laboratory inputs typical of university campuses in LMIC settings (Ajibade et al., 2014; Grimah et al., 2024). Geographic coordinates of each sampling location were recorded using a Global Positioning System and are presented in Table 1.

Sampling Design and Sample Collection

The sampling strategy was designed as a screening-level, reconnaissance assessment aimed at establishing baseline physicochemical characteristics in a data-limited context rather than estimating long-term average wastewater quality. Grab samples were collected from each selected discharge point on a single pre-monsoon day between 10:00 and 14:00, corresponding to peak campus activity when sanitary facilities, canteen operations, and laboratory usage are highest. This approach was adopted to capture representative peak-strength conditions, which are commonly used in preliminary institutional wastewater assessments where financial, logistical, and historical data constraints exist.

Sample Handling and Laboratory Analysis

Wastewater samples were collected in pre-cleaned 1,000 mL high-density polyethylene bottles. At each sampling location, bottles were rinsed with the respective wastewater prior to final collection. Field pH measurements were taken immediately using a calibrated portable multiparameter meter (KC-600, China). Samples were then placed in insulated containers and maintained at approximately 4 °C during transport to the laboratory, following sample preservation and holding-time guidelines specified in *Standard Methods* (APHA, 2012). Laboratory analyses included determination of TSS using the gravimetric method, BOD_5 using the azide modification method with a five-day incubation at 20 °C, and COD using the closed reflux method (APHA, 2012). Each parameter was analyzed in triplicate to assess analytical precision, and reported values represent arithmetic means of replicate measurements.

Quality Assurance and Quality Control (QA/QC)

QA/QC procedures were implemented to ensure internal consistency and reliability of the analytical results. All instruments were calibrated prior to analysis, and pH meters were standardized using buffer solutions at pH 4.0, 7.0, and 10.0. Laboratory glassware was acid-washed and thoroughly rinsed with distilled water to minimize contamination. All analyses were conducted using reagent-grade chemicals.

Data Analysis and Screening-level Treatability Indicators

Descriptive statistics were used to summarize physicochemical parameters across sampling locations. Preliminary treatability was evaluated using the ratios of BOD_5/COD and TSS/BOD_5 as screening-level indicators of organic biodegradability and solids characteristics, respectively. These ratios were interpreted qualitatively to support early-stage consideration of physical and biological treatment options and do not provide evidence of treatment efficiency or performance.

Results and Discussion

Physicochemical Characteristics of Campus Wastewater

The physicochemical characteristics of wastewater generated at the FWU central campus are summarized in Table 1. Wastewater pH values ranged from 7.8 to 9.0, with a mean value of 8.3 ± 0.63, indicating mildly alkaline conditions. These values comply with Nepal's effluent discharge standards (pH 6–9) (MoWS, 2023) and fall within the operational tolerance of conventional biological wastewater treatment processes, including aerobic systems (Bai et al., 2011; Tarpani & Azapagic, 2018). Mild alkalinity in institutional wastewater has been widely reported and is commonly associated to the presence of cleaning agents, organic nitrogen compounds, and intermittent laboratory discharges, particularly in campus environments where sanitary wastewater is mixed with non-residential inputs (Grimah et al., 2024; Vaibhav et al., 2018).

Table 1: Descriptive analysis of physicochemical parameters at FWU effluents points

Parameters/ Sampling site	Location	pH	TSS (mg/L)	BOD_5 (mg/L)	COD (mg/L)	$\frac{BOD_5}{COD}$	$\frac{TSS}{BOD_5}$
WW1	28°57'19.6"N 80°10'35.8"E	8.1	125	210	426	0.49	0.59
WW2	28°57'20.2"N 80°10'37.5"E	9	180	238	495	0.48	0.75
WW3	28°57'20.3"N 80°10'46.0"E	7.8	115	190	437	0.43	0.60
Mean ± Standard deviation		8.3 ± 0.63	140 ± 35	213 ± 24	453 ± 37	0.46 ± 0.03	0.64 ± 0.08
Nepal's wastewater effluent discharge standard (MoWS, 2023)		6-9	60	50	Monitor and report only		

TSS concentrations ranged from 115 to 180 mg/L, with a mean of 140 ± 35 mg/L, exceeding Nepal's effluent discharge limit of 60 mg/L by more than twofold (MoWS, 2023). Elevated TSS levels indicate a substantial particulate load, consistent with institutional wastewater influenced by sanitary cources, food residues from canteen operations, and fine inorganic particles from laboratory activities. Comparable TSS concentrations have been reported in campus-scale wastewater systems dominated by domestic sources but supplemented by institutional functions (Vaibhav et al., 2018;

Gursoy-Haksevenler & Arslan-Alaton, 2020). Operationally, higher suspended solids are significant because they can contribute to sludge accumulation, clogging of downstream units, and reduced disinfection efficiency if not adequately removed during preliminary and primary treatment stages (Gursoy-Haksevenler & Arslan-Alaton, 2020). The observed TSS concentrations therefore highlight the necessity of robust solids removal prior to biological treatment stage, consistent with highlighted in prior campus wastewater studies (Grimah et al., 2024; Lavanya et al., 2023).

BOD_5 concentrations ranged from 190 to 238 mg/L, with a mean of 213 ± 24.11 mg/L, while COD values ranged from 426 to 495 mg/L, with a mean 452.67 ± 37.07 mg/L. BOD_5 parameter substantially exceeded effluent discharge standard for BOD_5 (50 mg/L), indicating high biodegradable organic loading typical of sanitary and food-service contributions. COD values exceeded BOD_5 consistenly, implying the presence of additional oxidizable constituents beyond readily biodegradable organic, which may plausibly reflect mixed inputs that include laboratory-related compounds. Collectively, these results indicate that under current decentralized management practices and absence of centralized treatment, untreated campus wastewater constitutes a localized pollution concern.

Screening-level Treatability Indicators and Treatment Implications

The BOD_5/COD ratio ranged from 0.43 to 0.49, with a mean value of 0.46 ± 0.03. Consistent with screening-level interpretive frameworks, values above ~0.4 indicate that a substantial fraction of organic matter is readily biodegradable and that biological treatment is plausible, whereas lower ratios would suggest increasing refractory or inhibitory character (Abdalla & Hammam, 2014; Herrera et al., 2024). The ratios observed here align with values reported for institutional wastewater streams dominated by domestic and food-service inputs and are consistent with moderate biodegradability in mixed campus wastewater (Dhakal & Nakarmi, 2018; Grimah et al., 2024). However, because only bulk parameters were measured, these ratios cannot identify specific inhibitory constituents potentially present in laboratory discharges, nor can they be used to infer treatment performance.

The TSS/BOD_5 ratio varied from 0.59 to 0.75, with a mean of 0.64 ± 0.08. Lower ratios indicate that suspended solids loading is not disproportionately high relative to biodegradable organics, which supports the feasibility of primary solids removal as an effective upstream step. Relative to wastewaters where ratios exceed 1.0 and slower sedimentation is expected, the observed range suggests that primary sedimentation could meaningfully reduce particulate loading prior to biological treatment, thereby protecting downstream units and improving operability.

Collectively, the physicochemical characteristics and screening-level treatability indicators demonstrate that FWU wastewater exhibits a predominantly domestic profile in terms of organic strength and biodegradability, while exhibiting elevated suspended solids and organic loading relative to discharge standards. These findings support consideration of a treatment train emphasizing preliminary and primary solids removal (e.g., screening and sedimentation) followed by a biological process suited to moderate biodegradable loading. Nevertheless, interpretations must remain conservative, as characterization is based on single-event grab sampling and does not resolve temporal variability or unmeasured laboratory-derived constituents.

Strengths and Limitations

This study provides the first systematic baseline wastewater quality data for a representative institutional setting in Sudurpaschim Province, a critically understudied region. The findings provide an essential empirical foundation to inform university authorities, guide local management strategies, and frame future detailed investigations. However, conclusions regarding treatment design or performance validation are constrained by methodological limitations, primarily the restricted temporal scope of data collection. Characterization is based on grab samples collected during a single pre-monsoon period; consequently, reported statistics are more indicative of seasonal peak-strength conditions than annual average loadings required for detailed engineering design.

Conclusion

This study presents a physicochemical characterization and a screening-level evaluation of the treatability of wastewater generated at the central campus of Far Western University (FWU), Nepal, based on single-event grab samples collected from three representative institutional sources. The wastewater was mildly alkaline (pH 8.3 ± 0.63) and exhibited elevated concentrations of total suspended solids (TSS: 140 ± 35 mg/L), biochemical oxygen demand (BOD_5: 213 ± 24 mg/L), and chemical oxygen demand (COD: 453 ± 37 mg/L), all exceeding applicable effluent discharge standards. These results indicate that, under current management practices, untreated campus wastewater poses a localized pollution risk. Screening-level treatability indicators suggested the presence of a substantial biodegradable fraction. A mean BOD_5/COD ratio of 0.46 ± 0.03 reflected moderate biodegradability, while a TSS/BOD_5 ratio of 0.64 ± 0.08 indicated favorable conditions for solids sedimentation. Collectively, these indices suggest the preliminary suitability of a treatment strategy combining effective solids removal with biological treatment processes. However, these ratios were interpreted conservatively and are not sufficient to predict treatment efficiency or confirm process performance. From an engineering standpoint, the findings support consideration of a treatment train incorporating preliminary and primary solids removal followed by a biological treatment unit appropriate for moderate organic loading. Nevertheless, the reliance on single-day grab sampling constrains the representativeness of the dataset. Accordingly, the reported concentrations should be interpreted as indicative of peak-strength wastewater conditions rather than long-term average characteristics.

Conflict of Interests

The authors declare no conflict of interest.

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