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Assessing Treated Domestic Wastewater for Landscape Irrigation at a Residential Facility in Makassar, Indonesia: A Preliminary Study

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ABSTRACT

Reusing treated domestic wastewater for landscape irrigation requires assessing effluent quality. This study evaluated the preliminary suitability of domestic wastewater effluent from a residential facility in Makassar, Indonesia. A descriptive quantitative approach compared six parameters measured in September 2026 with Indonesian wastewater reuse criteria and calculated concentration-to-limit ratios. The effluent had a pH of 6.71, BOD_5 of 7 mg/L, COD of 54 mg/L, TSS of 4 mg/L, residual chlorine of 0.5 mg/L, and fecal coliforms of 180 MPN/100 mL. All measured parameters met the selected numerical criteria. Fecal coliforms and COD had the highest ratios (0.900 and 0.675, respectively), identifying monitoring priorities based on proximity to thresholds. These findings support preliminary consideration of the effluent for landscape irrigation. Integrating effluent quality control with irrigation demand and site conditions would support reuse planning and evaluation of potential freshwater savings.

Keywords: *Domestic Wastewater, Effluent Quality, Landscape Irrigation, Water Reuse, Water Conservation.*

1. INTRODUCTION

Growing pressure on freshwater resources requires exploring alternative water sources for landscape maintenance. The *United Nations World Water Development Report 2024* states that approximately half of the global population faces severe water scarcity during at least part of the year. Irrigating lawns, trees, and ornamental plants at residential facilities creates recurring demand and increases freshwater consumption. At facilities equipped with wastewater treatment plants (WWTPs), treated domestic effluent may serve as an alternative source to partially meet this demand. The feasibility of this application depends on the quality of the available water and the irrigation requirements of the receiving landscape [1], [2]. Wastewater management still faces substantial gaps worldwide. The *Sustainable Development Goals Report 2025* indicates that only 56% of the approximately 332 billion m^3 of domestic wastewater generated globally in 2024 was safely treated. This estimate draws on data from 130 Member States and 12 territories, covering 84% of the global population. The substantial volume of wastewater generated highlights the scale of treatment needs and the relevance of recovering water for suitable applications. At the facility level, planning for effluent reuse requires water-quality information to determine whether the available resource can support its proposed use [3].

Water savings through effluent reuse have been demonstrated in Indonesia. For example, a study at an industrial facility reported a water-use efficiency of 47.6% after reusing treated domestic wastewater for landscape irrigation, using all treated wastewater produced on site. The assessment integrated effluent quality evaluation with data on water availability and consumption. Potential savings at other facilities depend on effluent volume, irrigation demand, and operational factors. At residential facilities, the simultaneous presence of domestic wastewater generation and landscaped areas offers a relevant context for evaluating local effluent reuse opportunities [4].

Effluent quality is a critical factor in reuse planning, as treatment processes vary in their effectiveness at removing organic matter, suspended solids, microorganisms, and dissolved constituents. A demonstration-scale study in Chile found that tertiary treatment reduced total suspended solids by approximately 70%, five-day biochemical oxygen demand by 56%, and fecal coliforms by 99.9%. However, the treated effluent still exhibited an average electrical conductivity of 1,774 μS/cm and a total dissolved solids concentration of 964 mg/L, necessitating consideration of plant tolerance and irrigation management. Therefore, water-quality assessment for landscape irrigation must address characteristics pertinent to the intended application, including residual constituents in the effluent after treatment [5].

Environmental conditions in the receiving area also affect responses to irrigation with treated wastewater. A 13-month study of landscape plants in a coastal monsoon environment observed increased fluctuations in soil salinity, especially during periods of low rainfall. Reclaimed water irrigation altered soil nutrient dynamics and elicited varied responses among plant species, with some exhibiting signs of salt stress. These results highlight the interactions among water characteristics, climatic conditions, and vegetation tolerance under repeated irrigation. An initial effluent quality assessment can guide the selection of further investigations prior to implementation and inform monitoring priorities during subsequent reuse [2].

This study evaluates domestic WWTP effluent from a residential facility in Makassar, South Sulawesi, Indonesia. The analysis is based on laboratory test results from a sample collected at the WWTP outlet. Measured parameters include pH, five-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total suspended solids (TSS), residual chlorine, and fecal coliforms. These data provide a basis for assessing the effluent's preliminary suitability for landscape irrigation. The assessment is constrained by the limited set of measured parameters and the single sampling event, which limit effluent-quality characterization and highlight the need for further verification.

This study establishes a water-quality basis for evaluating effluent reuse at the residential facility. Decision-making in this context requires data on parameters that meet selected criteria, identification of constituents needing further control, and assessment of water characteristics warranting additional investigation. Accordingly, the study aims to assess the preliminary suitability of treated domestic wastewater for landscape irrigation by comparing laboratory results with relevant criteria and identifying needs for further testing or treatment. The findings are intended to inform wastewater reuse planning that addresses both freshwater conservation opportunities and the quality requirements of the intended application.

2. LITERATURE REVIEW

2.1 Treated Domestic Wastewater Reuse for Landscape Irrigation

Landscape irrigation enables facilities that generate wastewater and maintain vegetated areas to reuse treated domestic wastewater. The feasibility of this practice is

determined by effluent quality, available reuse volume, and irrigation demand. An Indonesian facility-level study evaluated these factors by analyzing wastewater characteristics, treatment processes, compliance with selected quality criteria, and water-use efficiency. The treatment system included biological treatment, clarification, filtration, and disinfection, showing that multiple treatment stages can produce effluent suitable for landscape irrigation [4].

The impact of reuse on freshwater conservation should be evaluated in each facility's specific operational context. Effluent quality determines compliance with selected requirements, while water availability and irrigation demand influence the volume that can be reused. The Indonesian study integrated these factors to estimate potential water savings. In laboratory-based assessments, the primary objective is to establish measured water-quality conditions and identify further information required for reuse planning. Accurate estimation of freshwater substitution requires data on effluent flow and irrigation demand [4].

2.2 Water-Quality Characteristics Relevant to Irrigation

Irrigation suitability is determined by multiple aspects of water quality. A study conducted in Al-Ahsa Oasis assessed organic matter indicators, nutrients, electrical conductivity, total dissolved solids, major ions, and irrigation water quality indices. The researchers collected 148 samples from various water sources across four sampling campaigns. The assessment included the sodium adsorption ratio and additional indices that address the composition of dissolved constituents. These measurements highlight the importance of salinity and ionic composition, in addition to conventional wastewater parameters, when evaluating irrigation water [6].

Treatment outcomes differ across various water-quality characteristics. In rural Chile, a study evaluated a tertiary treatment system that combined natural zeolite, activated carbon, and ultraviolet disinfection. This system improved removal of suspended solids, BOD_5, and fecal coliforms, although residual salinity remained significant for irrigation management. The findings support an assessment approach that considers both pollutants responsive to treatment and dissolved constituents remaining in the effluent. For the present study, available measurements of pH, BOD_5, COD, TSS, residual chlorine, and fecal coliforms serve as initial indicators. Additional characterization of electrical conductivity, dissolved solids, and major ions would further enhance the assessment of irrigation suitability [5].

2.3 Soil and Plant Responses to Repeated Irrigation

The effects of reclaimed-water irrigation result from interactions among water composition, soil properties, vegetation, and climate. A 13-month landscape study in a coastal monsoon environment documented changes in soil salinity, nutrient conditions, and enzyme activities. Salinity fluctuations were more significant during periods of low rainfall, and plant responses varied by species. Certain plants exhibited signs of salt stress, especially during the establishment phase. These findings indicate that the receiving landscape's response depends on both the characteristics of the applied water and prevailing environmental conditions [2]. Experimental evidence from greywater irrigation offers a complementary perspective on treatment efficacy and soil quality. A 14-month planter experiment utilized a soil quality index to assess changes under

various irrigation treatments. Soil irrigated with treated greywater maintained its quality, while raw greywater resulted in lower index scores. The study emphasized interpreting the overall index alongside individual indicators to identify the causes of observed changes. These findings support integrating water-quality characterization with measurements of the receiving soil when evaluating repeated irrigation. Applying these results to domestic WWTP effluent requires consideration of differences in wastewater composition and treatment processes [7].

2.4 Evidence Required for a Preliminary Suitability Assessment

Previous studies have assessed irrigation suitability using water-quality surveys, treatment trials, and soil–plant experiments. In Al-Ahsa, repeated sampling from various water sources enabled analysis of spatial and seasonal variation. Concurrently, the landscape experiment in a monsoon environment monitored changes in receiving soil and vegetation over time. These methodologies demonstrate that the scope of sampling and the outcomes measured directly influence the conclusions that can be drawn from an assessment [2], [6].

A preliminary assessment based on an outlet sample evaluates effluent quality at the time of sampling. Interpretation requires a clear comparison between each measured parameter and the criterion selected for the intended use. Parameters not included in the analytical dataset necessitate further investigation. Subsequent repeated sampling can determine whether observed conditions persist across operational periods, while monitoring soil and vegetation can assess responses after irrigation begins.

The present study applies this preliminary approach to a residential facility in Makassar. It evaluates available effluent measurements, links them to relevant irrigation criteria, and identifies the additional evidence needed to support reuse planning. The interpretation is limited to the measured parameters and sampling event. This scope provides a basis for deciding which aspects of water quality require verification before a broader assessment of operational and environmental suitability.

3. METHODS

3.1 Study Design and Location

A descriptive quantitative approach was employed to assess the preliminary suitability of treated domestic wastewater for landscape irrigation at a residential facility in Makassar, South Sulawesi, Indonesia. The assessment focused on effluent at the wastewater treatment plant (WWTP) outlet and compared its characteristics with domestic wastewater quality standards for irrigation reuse.

3.2 Observation Period and Analytical Parameters

The observation period was September 2026. Evaluated parameters included pH, five-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total suspended solids (TSS), residual chlorine, and fecal coliforms. Analytical methods are summarized in Table 1.

Table 1. Analytical methods for effluent quality testing

Parameter	Unit	Analytical method
pH	Dimensionless	SNI 6989.11:2019
BOD_5	mg/L	Standard Methods, APHA, 24th edition, Method 5210 B (2023)

COD	mg/L	SNI 6989.73:2019
TSS	mg/L	SNI 6989.3:2019
Residual chlorine	mg/L	Internal method using spectrophotometry
Fecal coliforms	MPN/100 mL	Standard Methods, APHA, 24th edition, Methods 9221 B, C, E, and F (2023)

3.3 Effluent Quality Assessment Criteria

Effluent quality was evaluated against domestic wastewater reuse standards specified in Regulation of the Minister of Environment/Environmental Control Agency of the Republic of Indonesia No. 11 of 2025, Annex I, Section B, Item 1. This provision addresses domestic wastewater reuse for irrigation and washing at businesses or activities outside the healthcare facility category. Reference values are provided in Table 2 [8].

Table 2. Domestic wastewater quality standards for reuse in watering

Parameter	Unit	Permitted range or maximum concentration
pH	Dimensionless	6–9
BOD	mg/L	12
COD	mg/L	80
TSS	mg/L	30
Residual chlorine	mg/L	1
Fecal coliforms	MPN/100 mL	200

Source: Regulation No. 11 of 2025, Annex I, Section B, Item 1. The residual chlorine criterion applies when chlorination is used. The regulation specifies direct pH measurement at the compliance point.

The measured BOD_5 value was compared with the regulatory BOD limit. The pH value was assessed against the permitted range, and the remaining parameters were compared with their respective maximum concentrations.

3.4 Data Analysis

Data werData were analyzed descriptively by organizing analytical results according to parameter, unit, and reference value. Concentration-based parameters met the numerical criteria if their measured values were equal to or below the corresponding maximum concentrations. The pH value met the criterion if it fell within the range of 6–9. The proximity of each concentration to its reference limit was assessed using the concentration-to-limit ratio, calculated as

$$R_i = \frac{C_i}{L_i} \quad (1)$$

where (Ri) is the dimensionless concentration-to-limit ratio, (Ci) is the measured concentration of parameter (i), and (Li) is its maximum permitted concentration. Values of (Ri \leq 1) indicate that the numerical criterion is met, while values of (Ri > 1) indicate an exceedance. A ratio approaching one signifies that the measured concentration is close to the maximum permitted value. The pH value was evaluated directly against its reference range.

The comparison identified parameters that met the criteria, exceeded the limits, and were closest to their respective limits. These findings formed the basis for determining monitoring priorities and potential treatment needs.

3.5 Preliminary Suitability Assessment for Landscape Irrigation

Preliminary suitability was assessed through a parameter-by-parameter comparison of effluent quality with the selected reuse criteria. Fulfillment of all measured numerical criteria was

interpreted as initial support for considering the effluent for landscape irrigation. Any exceedance identified the parameter requiring corrective treatment.

The assessment integrated conformity status and concentration-to-limit ratios to characterize effluent quality in relation to the proposed use. The resulting interpretation informed recommendations for effluent management and landscape irrigation planning at the residential facility.

4. RESULTS AND DISCUSSION

4.1 Effluent Quality and Conformity with the Selected Reuse Criteria

The domestic WWTP effluent exhibited a pH of 6.71, BOD_5 of 7 mg/L, COD of 54 mg/L, TSS of 4 mg/L, residual chlorine of 0.5 mg/L, and a fecal coliform concentration of 180 MPN/100 mL. All measured parameters satisfied the selected numerical criteria for domestic wastewater reuse in irrigation, as specified in Regulation No. 11 of 2025, Annex I, Section B, Item 1. These results provide a quantitative foundation for evaluating the effluent as a potential source for landscape irrigation at the residential facility. Table 3 presents the measured characteristics and their comparison with the reference criteria.

Table 3. Effluent quality and comparison with the selected reuse criteria

Parameter	Unit	Measured value	Reference criterion	Concentration-to-limit ratio, (R_i)	Assessment
pH	Dimensionless	6.71	6–9	—	Meets criterion
BOD_5	mg/L	7	12	0.583	Meets criterion
COD	mg/L	54	80	0.675	Meets criterion
TSS	mg/L	4	30	0.133	Meets criterion
Residual chlorine	mg/L	0.5	1	0.500	Meets criterion
Fecal coliforms	MPN/100 mL	180	200	0.900	Meets criterion

The numerical comparison demonstrates that the measured effluent met the selected criteria for all evaluated physicochemical and microbiological parameters. This outcome is significant to the study objective because it determines whether the effluent characteristics are suitable for the proposed irrigation application. Furthermore, the assessment quantifies each parameter's proximity to its reference value, providing operational insights beyond a simple pass/fail classification.

The concentration-to-limit ratios were ranked as follows: fecal coliforms, COD, BOD_5, residual chlorine, and TSS. Fecal coliforms reached 90.0% of the selected maximum, COD 67.5%, BOD_5 58.3%, residual chlorine 50.0%, and TSS 13.3%. Figure 1 presents these differences on a unified dimensionless scale.

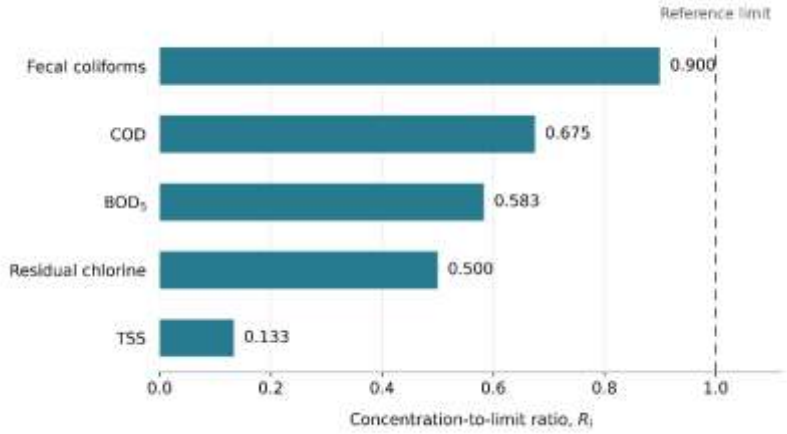


Figure 1. Concentration-to-limit ratios of the measured effluent parameters. The dashed line at (R_i = 1.0) represents the reference limit. The residual chlorine criterion applies when chlorination is used.

The graphical comparison elucidates the relationship between measured concentrations and their respective thresholds. Fecal coliforms were nearest to the reference line, whereas TSS exhibited the greatest separation. Each ratio is normalized to its respective criterion, enabling direct comparison across parameters with differing units and concentration ranges [9]. This ordering informs monitoring priorities based on proximity to the selected limits.

This interpretation is particularly valuable for facility management, since classifying all parameters as compliant does not indicate where increased operational attention is necessary. The ratio-based assessment identifies fecal coliforms and COD as the parameters requiring the most rigorous monitoring. These values can serve as benchmarks for evaluating future changes in effluent quality and for determining the need for operational adjustments [10].

4.2 pH and Organic Matter Characteristics

The effluent pH of 6.71 was within the permitted range of 6 to 9. This value indicates a slightly acidic condition and confirms compliance with the selected pH criterion for irrigation. The measured pH was 0.71 units above the lower boundary and 2.29 units below the upper boundary, providing a clear basis for the conformity assessment [11].

Interpreting pH in irrigation planning is enhanced by considering additional chemical characteristics. Research conducted in Al-Ahsa Oasis included electrical conductivity, dissolved solids, major ions, and sodium-related indices alongside pH to evaluate irrigation water from various sources. This investigation demonstrated the importance of comprehensive chemical characterization in identifying conditions relevant to irrigation management (Badr et al., 2023). For the present facility, pH informs the initial assessment, while further measurements of dissolved constituents would support decisions regarding soil and plant requirements. The measured BOD_5 was 7 mg/L, compared to a maximum of 12 mg/L. The concentration-to-limit ratio was 0.583, placing the measured value 41.7% below its reference maximum. COD was 54 mg/L, compared with a maximum of 80 mg/L, and had a ratio of 0.675. Its measured concentration was 32.5% below the selected limit. Both results support numerical compliance for the organic matter indicators evaluated in this study.

Distinguishing between absolute and normalized values is important for interpreting these results. BOD_5 was 5 mg/L below its limit, while COD was 26 mg/L below its limit. Although COD had a larger absolute difference, its ratio was higher because the reference concentrations differed. Normalization therefore identifies COD as the organic matter indicator closer to its threshold. This approach provides an operational basis for monitoring both indicators together. A subsequent

increase in either parameter would change its position relative to the selected maximum, while the ratio would indicate the extent of that movement. Maintaining a record of BOD_5 and COD alongside the corresponding ratios would facilitate interpretation of changes and support timely evaluation of treatment operation.

Evidence from a tertiary treatment investigation in Chile demonstrates that additional treatment can improve organic matter and suspended solids characteristics. A system combining natural zeolite, activated carbon, and ultraviolet disinfection achieved further reductions in BOD_5 and suspended solids, together with improvements in microbiological quality. Residual dissolved constituents remained relevant to irrigation management (González et al., 2026). For this assessment, the measured BOD_5 and COD values provide baseline effluent characteristics against which future treatment adjustments could be evaluated [5].

4.3 Suspended Solids and Their Operational Significance

TSS was measured at 4 mg/L, resulting in a concentration-to-limit ratio of 0.133. This value is 26 mg/L below the selected maximum of 30 mg/L, representing a proportional difference of 86.7%. Therefore, TSS exhibited the greatest separation from its reference threshold among the concentration-based parameters.

This result supports the assessment of effluent quality for the proposed irrigation application. The low relative position indicates that suspended solids were substantially below the selected maximum at the time of measurement [12]. Maintaining this condition should remain a priority in facility operations as the reuse arrangement is developed.

Suspended solids also have operational relevance within the treatment sequence. Water reuse guidance considers suspended solids and turbidity when specifying treatment conditions, including the quality of water entering disinfection processes [13]. This relationship supports evaluating TSS results alongside microbiological measurements when reviewing treated effluent quality.

The contrast in threshold proximity between TSS and fecal coliforms is illustrated in Figure 1 [14]. TSS reached only 13.3% of its maximum, whereas fecal coliforms reached 90.0%. This difference underscores the importance of interpreting individual parameters separately during operational assessment. Maintaining the current suspended solids level remains important, while the microbiological result requires closer monitoring because it is close to the selected threshold.

Fecal coliforms were measured at 180 MPN/100 mL, compared to a maximum of 200 MPN/100 mL. This value met the selected numerical criterion, falling 20 MPN/100 mL below the limit. The concentration-to-limit ratio of 0.900 was the highest among the evaluated parameters, identifying fecal coliforms as the principal monitoring priority based on proximity to the threshold. The difference below the limit represents 10% of the reference concentration, indicating how close the measured value is to the selected maximum. This finding supports closer monitoring of microbiological quality when planning effluent reuse, particularly because maintaining compliance is essential throughout operation. The residual chlorine result was 0.5 mg/L below the 1 mg/L maximum used in the assessment, corresponding to a concentration-to-limit ratio of 0.500. The applicable regulation specifies the residual chlorine criterion for domestic wastewater treatment involving chlorination [8].

Residual chlorine measurements and fecal coliform results provide complementary information for evaluating disinfection when chlorination is used. Water reuse guidance considers chlorine residual, contact time, and microbiological performance when assessing disinfection conditions [13]. Reviewing these factors together would help facility operators determine whether the treatment conditions consistently support the intended microbiological quality.

The combined results indicate that verifying operational conditions should be a management priority. When chlorination is applied, dosing consistency and contact conditions should be reviewed in conjunction with repeated measurements of residual chlorine and fecal coliforms. The objective is to maintain microbiological conformity while ensuring residual chlorine

remains within the selected criterion. These findings support this targeted approach, as the two measurements fall in different positions relative to their respective reference limits.

Microbiological performance has also been evaluated as part of integrated tertiary treatment research. The investigation in Chile assessed fecal coliform reduction alongside organic matter, suspended solids, and dissolved constituents [5]. This approach shows the importance of assessing overall treated-water quality when considering reuse. At the residential facility, maintaining the observed physicochemical quality while closely tracking fecal coliforms would address the main priority identified by the ratio analysis.

4.4 Implications for Landscape Irrigation and Freshwater Conservation

The measured effluent characteristics provide preliminary support for landscape irrigation at the residential facility. All six parameters satisfied the selected numerical criteria, and the ratio analysis identified fecal coliforms and COD as closest to their respective limits. This assessment therefore provides both an initial evaluation of water quality and a foundation for directing operational attention.

These findings directly address the need for alternative water sources outlined in the introduction. Landscape maintenance generates recurring water demand, and treated domestic effluent represents a potential internal supply. Establishing the measured quality of this supply is a necessary first step in evaluating its suitability for irrigation. The present results support assessing how the available effluent volume matches the location, timing, and quantity of irrigation demand. Evidence from Indonesia demonstrates the potential contribution of facility-level reuse to freshwater conservation. A study combining effluent quality assessment with water-use information reported a water-use efficiency of 47.6% after reusing treated domestic wastewater for landscape watering [4]. The result illustrates a measurable conservation benefit under the conditions examined. For the residential facility in Makassar, the potential substitution volume would be determined by matching effluent availability with actual watering demand.

The receiving landscape also influences the suitability of the proposed application. A 13-month investigation in a coastal monsoon environment found that reclaimed water irrigation altered soil salinity and nutrient conditions, with different responses among landscape plant species. Salinity fluctuated during periods of low rainfall, and some species showed signs of salt stress [2]. These observations support considering rainfall, soil characteristics, and plant tolerance when developing irrigation practices.

Additional characterization of electrical conductivity, dissolved solids, and major ions would help connect effluent composition with these landscape conditions. Irrigation studies have used these measurements and associated indices to evaluate salinity and sodium-related constraints across different water sources [6]. Incorporating this information into reuse planning would help select suitable vegetation and develop soil and water management practices.

This assessment's practical significance lies in establishing a water-quality foundation for the proposed reuse application. Numerical compliance across the measured parameters supports further consideration of landscape irrigation, while the concentration-to-limit ratios highlight priorities for maintaining effluent quality. Fecal coliforms and COD require the closest monitoring because they are closest to threshold values. Integrating these findings with effluent availability, irrigation demand, and landscape conditions provides a basis for planning reuse and evaluating its contribution to freshwater conservation.

5. CONCLUSION

Treated domestic wastewater from the residential facility in Makassar satisfied the selected numerical criteria for reuse in landscape irrigation across all six evaluated parameters. The measured values were pH 6.71, BOD_5 7 mg/L, COD 54 mg/L, TSS 4 mg/L, residual chlorine 0.5 mg/L, and fecal

coliforms 180 MPN/100 mL. These results offer preliminary evidence supporting the consideration of the effluent as an alternative water source for landscape irrigation.

The concentration-to-limit assessment indicated that fecal coliforms and COD were closest to their respective thresholds, with ratios of 0.900 and 0.675. These parameters should be prioritized for monitoring to ensure effluent quality, whereas TSS exhibited the greatest margin from its reference limit. Integrating effluent quality control with water availability, irrigation demand, and receiving landscape conditions would facilitate reuse planning and enable assessment of potential freshwater savings at the facility.

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