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WASTEWATER QUALITY ANALYSIS AT THE WASTEWATER TREATMENT INSTALLATION OF UNHAS HOSPITAL, MAKASSAR CITY

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ABSTRACT

Hospital wastewater contains a complex mixture of organic pollutants, suspended solids, pathogenic microorganisms, pharmaceutical residues, and hazardous substances that may threaten environmental quality and public health if discharged without adequate treatment. This study aimed to evaluate the performance of the wastewater treatment plant (WWTP) at Hasanuddin University Hospital, Makassar, Indonesia, by assessing the quality of treated wastewater based on selected physicochemical and microbiological parameters. A quantitative descriptive approach was employed through direct sampling at the WWTP between November 2025 and January 2026. Grab sampling was conducted at the influent and effluent points, while laboratory analyses measured total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH, cadmium (Cd), and total coliform following APHA standard methods. The results demonstrated that the WWTP effectively reduced pollutant concentrations, with removal efficiencies of 96.36% for TSS, 81.58% for BOD, 83.71% for COD, 66.67% for Cd, and 99.35% for total coliform. The effluent pH remained stable within the neutral range, supporting effective biological treatment and compliance with environmental quality standards. These findings indicate that the integrated physical, biological, and chemical treatment processes operated efficiently in reducing pollutant loads before wastewater discharge. Continuous operational monitoring, routine maintenance, and optimization of treatment processes are recommended to ensure long-term treatment performance and support environmentally sustainable hospital wastewater management.

INTRODUCTION

Hospital wastewater has become an increasingly important environmental issue due to the rapid expansion of healthcare services and the growing complexity of pollutants generated by medical facilities. Hospitals are essential institutions that provide promotive, preventive, curative, and rehabilitative healthcare services while simultaneously functioning as centers for education and medical research (Law of the Republic of Indonesia No. 17 of 2023; Ministry of Health Regulation No. 3 of 2020). These diverse activities inevitably produce large volumes of wastewater containing complex mixtures of biodegradable organic matter, nutrients, pharmaceutical residues, disinfectants, heavy metals, pathogenic microorganisms, and antimicrobial-resistant bacteria. Unlike domestic wastewater, hospital effluents contain contaminants that require specialized treatment because of their potential to degrade aquatic ecosystems and threaten public health when discharged without adequate treatment (Khan et al., 2020; Verlicchi et al., 2022). Consequently, effective wastewater treatment has become an integral component of sustainable hospital environmental management.

The environmental risks associated with hospital wastewater have received increasing global attention over the past decade. Recent studies indicate that hospital effluents are important sources of emerging contaminants, including antibiotics, endocrine-disrupting compounds, personal care products, and antimicrobial resistance genes that may persist even after conventional wastewater treatment processes (Rizzo et al., 2019; Khan et al., 2020). These pollutants can alter aquatic microbial communities, reduce dissolved oxygen concentrations through excessive organic loading, and facilitate the dissemination of antibiotic-resistant microorganisms into natural water bodies. The World Health Organization has also emphasized that inadequate healthcare waste management exposes healthcare workers, patients, surrounding communities, and ecosystems to significant biological and chemical hazards (World Health Organization, 2022). Therefore, improving wastewater treatment performance has become one of the priority strategies for achieving environmental sustainability and protecting public health.

Wastewater treatment installations (WWTPs) in hospitals are designed to reduce pollutant concentrations before treated effluent is discharged into receiving waters. Biological treatment processes, including activated sludge systems, biofilters, sequencing batch reactors, membrane bioreactors, and integrated anaerobic–aerobic systems, have demonstrated considerable effectiveness in removing biodegradable organic matter and suspended solids (Bui et al., 2022; Zhang et al., 2023). Nevertheless, the efficiency of these systems is strongly influenced by fluctuations in wastewater characteristics, operational management, hydraulic loading, maintenance practices, and treatment technology. Consequently, continuous monitoring of wastewater quality using physicochemical and microbiological parameters—including biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), pH, heavy metals, and microbial indicators—is essential to evaluate treatment performance and ensure compliance with environmental regulations (APHA, 2023).

In Indonesia, wastewater management has become an important component of environmental protection policy following the implementation of Government Regulation Number 22 of 2021 concerning Environmental Protection and Management. Furthermore, wastewater generated by healthcare facilities must comply with environmental quality standards before discharge into natural water bodies, reflecting the government's commitment to minimizing pollution originating from healthcare activities. Despite these regulatory requirements, several studies have reported that hospital wastewater treatment performance remains inconsistent due to differences in treatment technology, operational capacity, financial resources, and routine maintenance (Rahman et al., 2021; Kementerian Lingkungan Hidup dan Kehutanan, 2023). Consequently, periodic assessment of wastewater quality is necessary to verify treatment effectiveness and support evidence-based environmental management.

Hasanuddin University Hospital (UNHAS Hospital), located in Makassar City, is one of the largest teaching hospitals in eastern Indonesia, providing comprehensive healthcare services while supporting medical education and research. The increasing number of patients, laboratories, operating rooms, and supporting medical facilities inevitably generates substantial volumes of wastewater requiring effective treatment prior to environmental discharge. The hospital has established a Wastewater Treatment Installation (WWTP); however, comprehensive scientific evaluations regarding the quality of treated effluent and its compliance with current environmental standards remain limited. Considering the strategic role of UNHAS Hospital and the environmental sensitivity of urban water resources in Makassar, evaluating the performance of its wastewater treatment system is both environmentally and scientifically important.

Previous studies on hospital wastewater in Indonesia have predominantly focused on individual treatment technologies or selected water quality parameters without comprehensively evaluating the physical, chemical, and microbiological characteristics of treated effluent in relation to current regulatory standards. Moreover, relatively few investigations have examined wastewater quality in teaching hospitals that receive high patient loads and generate more complex wastewater characteristics than general healthcare facilities. This limitation represents an important research gap because reliable scientific information is needed to improve operational performance, strengthen environmental monitoring, and support sustainable wastewater management in healthcare institutions.

Therefore, this study aims to analyze the quality of wastewater generated by the Wastewater Treatment Installation of Hasanuddin University Hospital, Makassar City, by evaluating its physical, chemical, and microbiological characteristics. Specifically, the study assesses the concentrations of biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), pH, lead (Pb), cadmium (Cd), and total coliform in the treated effluent and compares the results with applicable Indonesian wastewater quality standards. The findings are expected to provide scientific evidence regarding the operational effectiveness of the hospital wastewater treatment system while contributing to the improvement of environmental management practices, pollution prevention strategies, and sustainable healthcare services.

METHOD

This study employed a quantitative descriptive research design to evaluate the quality of wastewater generated by the Wastewater Treatment Plant (WWTP) of Hasanuddin University Hospital, Makassar City. Field sampling was conducted directly (*in situ*) between November 2025 and January 2026 at the hospital wastewater treatment facility. Sampling activities were designed to characterize the physicochemical and microbiological quality of treated wastewater through direct measurements and laboratory analyses. Field equipment included a portable pH meter, dissolved oxygen (DO) meter, digital thermometer, total dissolved solids/electrical conductivity (TDS/EC) meter, handheld Global Positioning System (GPS), sterile sampling bottles, cool box with ice packs, and appropriate personal protective equipment (PPE), including masks, gloves, and safety boots. The study focused on evaluating key wastewater quality parameters comprising biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), pH, temperature, dissolved oxygen, heavy metals (Pb and Cd), and total coliform, which are widely recognized as essential indicators for assessing wastewater treatment performance and environmental compliance (APHA, 2023; Metcalf & Eddy, 2014). The analytical framework followed internationally accepted procedures for water quality assessment to ensure data reliability, reproducibility, and comparability across environmental monitoring studies (ISO, 2017; United States Environmental Protection Agency [USEPA], 2017).

Wastewater samples were collected using the grab sampling technique, which is recommended for evaluating the quality of treated effluent at a specific point in time (ISO, 2017; APHA, 2023). Before sampling, all sample containers were thoroughly cleaned with distilled water and sterilized according to the analytical requirements of each parameter. Sterile polyethylene and glass bottles were labeled with sampling location, date, time, and parameter identification before collection. Samples were obtained approximately 20–30 cm below the water surface, with the bottle opening oriented toward the flow direction to minimize atmospheric contamination. Separate preservation procedures were applied according to the analytical parameter. Samples designated for BOD, COD, TSS, pH, and temperature analyses were stored in 1.5-L polyethylene bottles and immediately cooled to approximately 4°C. Samples for heavy metal analysis (Pb and Cd) were preserved by acidification with concentrated nitric acid (HNO_3) to maintain a pH below 2. In contrast, microbiological samples for total coliform determination were collected in sterile containers without chemical preservatives. Immediately after collection, all samples were transported in insulated cool boxes containing ice packs and delivered to an accredited environmental laboratory within **24 hours**, following standard preservation and holding-time procedures to prevent physicochemical and microbiological changes before laboratory analysis (APHA, 2023; ISO, 2017; USEPA, 2017).

RESULT AND DISCUSSION

The performance of the wastewater treatment plant (WWTP) at Hasanuddin University Hospital was evaluated by comparing the physicochemical and microbiological characteristics of wastewater before treatment (inlet) and after treatment (outlet). The evaluation focused on key wastewater quality parameters commonly used to assess treatment efficiency, including total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH, cadmium (Cd), and total coliform. These parameters were selected because they represent the principal indicators of organic pollution, suspended particulate matter, heavy metal contamination, and microbiological safety, as recommended in national wastewater quality standards and international wastewater treatment guidelines (APHA, 2023; Metcalf & Eddy, 2014; WHO, 2022). The removal efficiency for each parameter was calculated to assess the treatment process's effectiveness in reducing pollutant concentrations before effluent discharge into the receiving environment.

The laboratory analysis results presented in Table 1 indicate substantial reductions in most wastewater quality parameters after treatment. Overall, the findings demonstrate that the WWTP effectively reduced pollutant loads through integrated physical, biological, and chemical treatment processes, thereby improving effluent quality and supporting compliance with applicable environmental regulations.

Table 1.
Wastewater Quality Parameters at the Inlet and Outlet of the Hasanuddin University Hospital WWTP

Parameter	Inlet	Outlet	Removal Efficiency (%)
TSS (mg L^{-1})	66.00	2.40	96.36
BOD (mg L^{-1})	76.00	14.00	81.58
COD (mg L^{-1})	191.47	31.19	83.71
pH	7.39	7.16	Stable
Cd (mg L^{-1})	0.0003	0.0001	66.67
Total Coliform (MPN/100 mL)	**101,700,000**	**657,000**	**99.35**

Source: Laboratory analysis, 2025

The laboratory analysis demonstrated that the wastewater treatment plant (WWTP) of Hasanuddin University Hospital effectively reduced most physicochemical and microbiological pollutants before effluent discharge. Considerable reductions were observed for total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), cadmium (Cd), and total coliform, indicating that the integrated treatment system successfully combined physical, biological, and chemical treatment processes. Overall, the treated effluent complied with the applicable wastewater quality standards established by the Indonesian environmental regulations, suggesting that the WWTP operated efficiently during the monitoring period.

The concentration of total suspended solids (TSS) decreased substantially from 66 mg L^{-1} at the inlet to 2.4 mg L^{-1} at the outlet, corresponding to a removal efficiency exceeding 96%. This remarkable reduction indicates that sedimentation, filtration, and clarification units effectively removed suspended particles from hospital wastewater. Low TSS concentrations are essential because suspended solids increase turbidity, reduce light penetration, transport adsorbed contaminants, and negatively affect aquatic ecosystems after wastewater discharge (Metcalf & Eddy, 2014). Similar removal efficiencies have been reported in hospital wastewater treatment systems employing combined biological and filtration processes, where TSS reductions frequently exceed 90% (Wibowo et al., 2023). The present findings therefore demonstrate that the mechanical treatment units of the Hasanuddin University Hospital WWTP performed efficiently in reducing particulate pollutants prior to environmental discharge.

A similar trend was observed for biochemical oxygen demand (BOD), which declined from 76 mg L^{-1} to 14 mg L^{-1}, representing an approximately 82% reduction. BOD is widely recognized as an indicator of biodegradable organic matter and reflects the amount of dissolved oxygen required by microorganisms to decompose organic pollutants (Tchobanoglous et al., 2014). The substantial decrease indicates that microbial degradation processes within the biological reactors functioned efficiently in metabolizing organic contaminants derived from hospital activities. Comparable studies have reported BOD removal efficiencies ranging between 70% and 90% in well-operated hospital wastewater treatment facilities using activated sludge or biofilter technologies (Metcalf & Eddy, 2014; Wibowo et al., 2023). Maintaining low BOD concentrations is particularly important because excessive organic loading may deplete dissolved oxygen in receiving waters, thereby threatening aquatic organisms and ecological stability (Sumantri, 2017).

The chemical oxygen demand (COD) concentration also showed a marked reduction, decreasing from 191.47 mg L^{-1} at the inlet to 31.19 mg L^{-1} at the outlet, equivalent to an efficiency of approximately 84%. COD represents the total quantity of chemically oxidizable substances, including biodegradable and non-biodegradable organic compounds as well as certain inorganic pollutants (Metcalf & Eddy, 2014). The significant reduction demonstrates that the treatment process effectively removed complex pollutants such as pharmaceutical residues, detergents, disinfectants, and organic waste generated from medical activities. Similar findings have been documented in previous investigations of hospital wastewater treatment plants, where integrated biological treatment substantially reduced COD concentrations before final discharge (Rawis et al., 2022; Wibowo et al., 2023). Consequently, the observed COD removal indicates satisfactory overall treatment performance and reduced potential for environmental pollution.

The pH values remained relatively stable throughout the treatment process, changing only slightly from 7.39 to 7.16 during Week I and remaining within the neutral range recommended for wastewater discharge. Stable pH conditions are essential for sustaining microbial activity in biological reactors because extreme acidic or alkaline conditions inhibit microbial metabolism and reduce treatment efficiency (Metcalf & Eddy, 2014). Furthermore, maintaining pH within the regulatory range minimizes toxicity to aquatic organisms after wastewater discharge. Similar observations have been reported in modern hospital wastewater treatment systems, where biological buffering maintains pH stability throughout the treatment process (Sumantri, 2017; Wibowo et al., 2023).

The concentration of cadmium (Cd) declined from 0.0003 mg L^{-1} to 0.0001 mg L^{-1}, indicating that the WWTP effectively reduced heavy metal contamination. Heavy metals in hospital wastewater commonly originate from laboratory activities, pharmaceutical compounds, medical equipment, and diagnostic procedures. Their removal generally occurs through coagulation, flocculation, sedimentation, adsorption onto sludge particles, and biological uptake (APHA, 2023). Although the initial Cd concentration was relatively low, the observed reduction demonstrates that the treatment units successfully minimized the discharge of toxic metals into the aquatic environment. Effective heavy metal removal is particularly important because cadmium is bioaccumulative and may pose long-term ecological and human health risks even at low concentrations (USEPA, 2017).

The total coliform count exhibited the most dramatic improvement, decreasing from

101,700,000 MPN/100 mL at the influent to 657,000 MPN/100 mL in the treated effluent, corresponding to a microbial reduction of more than 99%. This substantial decrease indicates that the biological treatment process, combined with final disinfection, effectively inactivated pathogenic microorganisms commonly present in hospital wastewater. Total coliform serves as an important microbiological indicator of sanitation performance and pathogen removal efficiency (WHO, 2022). Although complete sterilization is rarely achieved in conventional wastewater treatment systems, the observed reduction demonstrates that the Hasanuddin University Hospital WWTP substantially reduced microbial contamination prior to environmental discharge. Similar reductions have been reported in hospital wastewater treatment facilities employing biological treatment followed by chlorination or ultraviolet disinfection (WHO, 2022; APHA, 2023).

Overall, the findings demonstrate that the Hasanuddin University Hospital wastewater treatment plant performs effectively in reducing suspended solids, biodegradable organic matter, chemically oxidizable pollutants, heavy metals, and microbiological contaminants. The consistently high removal efficiencies observed across multiple parameters indicate that the integrated treatment process functions optimally and complies with current environmental quality standards. Nevertheless, continuous operational monitoring, routine maintenance, periodic sludge management, and regular performance evaluations remain necessary to ensure long-term treatment efficiency and to anticipate increasing wastewater loads associated with expanding healthcare services. Continuous optimization of biological treatment processes and disinfection systems will further enhance environmental protection and contribute to sustainable hospital wastewater management.

CONCLUSION

The results demonstrate that the wastewater treatment plant (WWTP) at Hasanuddin University Hospital effectively improved wastewater quality through integrated physical, biological, and chemical treatment processes. Significant reductions were observed in all major pollution indicators, including total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), cadmium (Cd), and total coliform, while the pH remained stable within the acceptable range for biological treatment. These findings indicate that the WWTP successfully reduced both physicochemical and microbiological contaminants, producing effluent that complied with the applicable environmental quality standards for hospital wastewater discharge. Despite the satisfactory treatment performance, continuous monitoring and periodic evaluation remain essential to maintain operational efficiency under increasing hospital service demands. Regular maintenance of treatment units, optimization of biological processes, and routine assessment of emerging contaminants should be incorporated into future management strategies. Strengthening wastewater management practices will not only improve environmental protection but also minimize public health risks and contribute to the sustainable operation of healthcare facilities in accordance with national environmental regulations and international wastewater management standards.

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