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Spatial Assessment of Organic Pollution in Three Major Lakes of Türkiye: A Comparative Analysis of BOD and COD Levels in Manyas, Uluabat, and İznik Lakes

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Abstract

This study investigates the spatial distribution and comparative water quality status of Manyas, Uluabat, and İznik Lakes using Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) as key indicators of organic pollution. Water samples collected in spring 2025 were analysed, and GIS-based mapping approaches was applied to reveal spatial variability and pollution patterns. Results showed that Uluabat Lake generally exhibited good water quality with low organic load, İznik Lake reflected mostly moderate conditions with localized impacts, while Manyas Lake displayed considerably higher BOD and COD values, indicating stronger organic pollution pressure. According to the Turkish Water Pollution Control Regulation, Manyas Lake was classified at higher pollution classes in several stations, whereas the other two lakes remained largely within lower classes. Overall, the findings highlight clear differences in anthropogenic pressure among the studied lakes and emphasize the importance of continuous monitoring and effective watershed management to protect these ecologically and economically significant freshwater systems.

Keywords: *Manyas Lake, Uluabat Lake, İznik Lake, BOD, COD, water quality, GIS*

Introduction

Freshwater contamination has become one of the most severe environmental problems, with wide-ranging impacts on aquatic ecosystems, biodiversity, and human well-being (Tokatlı et al., 2017; Helvacıoğlu et al., 2025; Haq et al., 2023; Din et al., 2023). Lakes, as key components of inland water resources, play a fundamental role in drinking water supply, irrigation, fisheries, and ecological stability. However, increasing human-induced pressures such as agricultural drainage, industrial effluent discharge, and the input of untreated domestic wastewater have significantly contributed to the deterioration of lake water quality in many regions (Tokatlı, 2019; 2020a; 2020b; Çiçek et al., 2014; Köse et al., 2020; Varol et al., 2022; Ustaoğlu et al., 2022; Yüksel et al., 2024). These pressures not only alter the physicochemical structure of aquatic environments but also disrupt ecosystem functioning and reduce the resilience of freshwater systems.

Freshwater ecosystems are particularly sensitive to organic pollution, which is commonly evaluated using Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). These two parameters are widely recognized indicators that reflect biodegradable organic matter and total oxidizable substances in water, respectively. Their combined assessment provides a comprehensive understanding of organic pollution dynamics and ecosystem health. In many lake systems, elevated BOD and COD levels are closely associated with nutrient enrichment, microbial activity, and oxygen depletion, which may ultimately lead to ecosystem degradation. Therefore, analyzing spatial and temporal variations in these parameters is essential for identifying pollution hotspots, understanding contaminant pathways, and evaluating the ecological response of aquatic environments to anthropogenic stressors (Muhammad et al., 2024; 2025; Tokatlı et al., 2025).

Within this context, Manyas Lake, Uluabat Lake, and İznik Lake represent three ecologically and socioeconomically important freshwater systems in northwestern Türkiye. These lakes differ in terms of hydrological characteristics, surrounding land use patterns, and the intensity of human activities within their catchments, resulting in variable levels of environmental pressure. This study aims to evaluate the spatial distribution and comparative water quality status of these three lakes based on BOD and COD parameters. By integrating GIS-based spatial analysis with statistical evaluation, the research identifies spatial variability in organic pollution levels and classifies water quality according to the Turkish Water Pollution Control Regulation. The outcomes are expected to contribute to a better understanding of anthropogenic impacts on these lake ecosystems and to provide a scientific basis for effective and sustainable water resource management strategies.

Materials and Methods

Selected locations and sample collection

Figure 1 presents the map of the studied lakes together with the selected sampling sites. Water samples were collected in spring 2025. Subsurface samples were obtained using a telescopic water sampler from approximately 2.5–3 m offshore and transferred into 500 mL polyethylene bottles. All samples were preserved at 4 °C in accordance with APHA (2017) guidelines and subsequently transported to Trakya University for laboratory analyses.

Figure 1. Marmara Basin, investigated lakes and selected sampling stations

BOD – COD analysis

Biochemical Oxygen Demand (BOD) was determined using a Hach BOD Trak II system based on the standard 5-day incubation method (BOD_5), which measures the amount of oxygen consumed by microorganisms during the degradation of biodegradable organic matter. Chemical Oxygen Demand (COD) was analysed using a Hach DR3900 spectrophotometer, based on the dichromate digestion method, which quantifies the total amount of oxidizable substances present in the samples. All analyses were conducted in accordance with APHA standard methods (1998), and appropriate quality control procedures were applied to ensure the accuracy and reliability of the results.

Results and Discussion

The spatial distribution of BOD and COD values obtained in this study is presented as GIS-based maps in Figure 2 and as graphical representations in Figure 3, allowing a clear visualization of both spatial variability and comparative trends among the studied lakes.

Biochemical Oxygen Demand (BOD) values show clear differences among the three lakes when evaluated according to the Turkish Water Pollution Control Regulation. In Uluabat Lake, BOD concentrations ranged between 1.6 and 3.1 mg/L, with a mean of 2.28 mg/L, indicating that all stations fall within the 1st class water quality category (<4 mg/L) (TSWQR, 2021). This suggests low levels of biodegradable organic matter and relatively good ecological conditions. In contrast, Manyas Lake exhibited substantially higher BOD levels (2.4–11.0 mg/L; mean: 6.14 mg/L), corresponding to 2nd (4-8 mg/L) and 3rd (>8 mg/L) class water quality (TSWQR, 2021). Particularly, stations M3 and M4 exceeded 8 mg/L, indicating significant organic pollution and increased microbial oxygen consumption. İznik Lake displayed intermediate conditions, with BOD values ranging from 1.7 to 6.3 mg/L (mean: 2.77 mg/L). Most stations were classified as 1st class, while a few (e.g., İ1) reached 2nd class levels, reflecting localized organic inputs (TSWQR, 2021). Overall, BOD results indicate that Uluabat Lake maintains high water quality, İznik Lake is generally good with minor localized impacts, and Manyas Lake is under more pronounced organic pollution pressure.

Chemical Oxygen Demand (COD) results further support these findings and reveal differences in both biodegradable and non-biodegradable organic loads. Uluabat Lake showed COD values between 11.9 and 18.3 mg/L (mean: 15.7 mg/L), consistently within the 1st class category (<25 mg/L), indicating low overall organic pollution. In Manyas Lake, COD concentrations were markedly elevated, ranging from 39.5 to 65.1 mg/L with a mean of 56.3 mg/L, corresponding predominantly to 3rd class water quality (>50 mg/L) (TSWQR, 2021). These high values suggest substantial inputs of oxidizable substances, including more resistant organic compounds, likely linked to intensive anthropogenic activities. İznik Lake exhibited COD values between 18.5 and 25.6 mg/L (mean: 21.5 mg/L), placing most stations in the 1st class, with a few measurements approaching or slightly exceeding the threshold into 2nd class (25-50 mg/L) (TSWQR, 2021). This indicates generally good water quality with occasional moderate pollution signals. Collectively, COD data confirm that Manyas Lake is the most impacted system, while Uluabat and İznik lakes exhibit comparatively lower levels of organic contamination.

Elevated BOD and COD levels can accelerate eutrophication, a process in which excessive nutrient and organic matter inputs stimulate algal blooms, ultimately leading to oxygen depletion and disruptions in the aquatic food web. In natural lake systems, increased BOD and COD concentrations are commonly associated with external inputs such as agricultural runoff and untreated or partially treated wastewater discharges. Agricultural activities contribute substantial amounts of organic matter and nutrients through fertilizers, animal waste, and soil erosion, while domestic and industrial effluents further intensify the organic and chemical load (Mutlu et al., 2021a; 2021b; Tokatlı et al., 2023; 2024). These combined pressures enhance microbial activity, increasing oxygen consumption and potentially resulting in hypoxic conditions, which can negatively affect aquatic organisms and overall ecosystem health. In this context, the relatively high BOD and COD values observed in Manyas Lake are likely linked to intensive agricultural practices in the surrounding basin, together with domestic wastewater inputs from nearby settlements. Such conditions indicate a substantial organic pollution burden and suggest that the lake is vulnerable to ongoing eutrophication processes if these pressures persist.

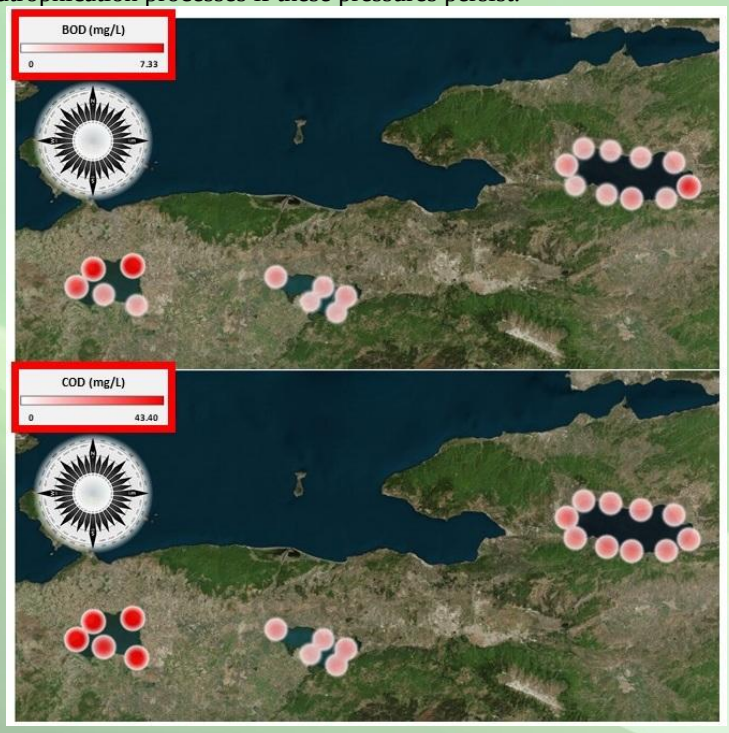

Figure 2. GIS-based BOD-COD distribution maps

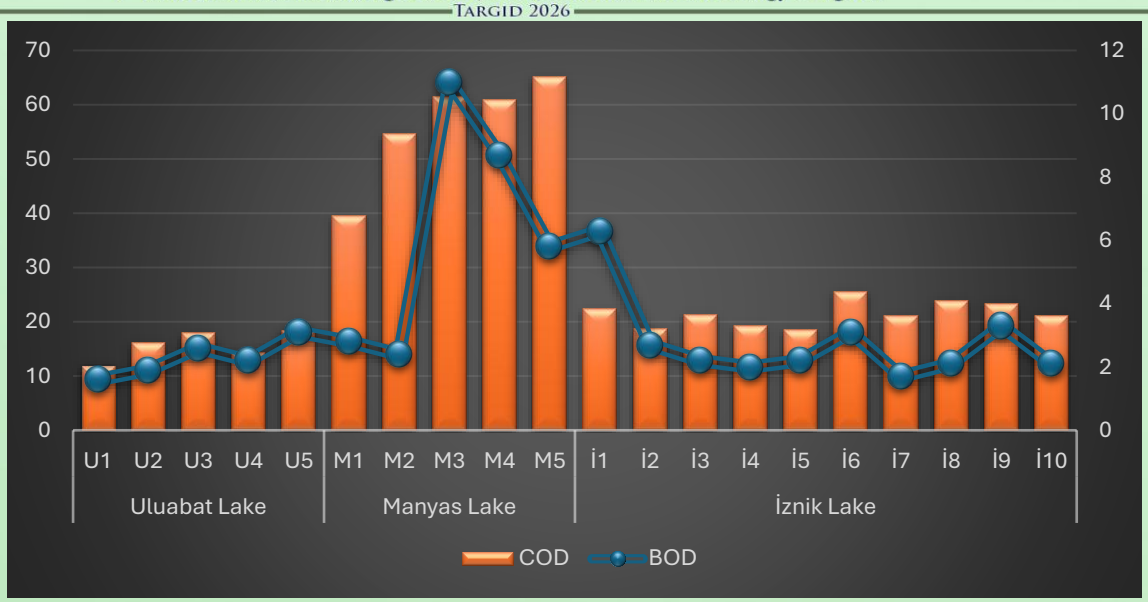

Figure 3. BOD-COD concentrations in water of investigated lakes

Conclusions

Overall, the combined evaluation of BOD and COD results demonstrates a distinct gradient of organic pollution among the lakes. Uluabat Lake consistently exhibits low BOD and COD levels, corresponding to 1st class water quality, indicating limited organic loading and relatively stable ecological conditions. İznik Lake generally reflects good water quality, with most stations classified as 1st class and only minor deviations toward 2nd class, suggesting localized and moderate anthropogenic influences. In contrast, Manyas Lake shows markedly elevated BOD and COD values, frequently falling into 2nd and 3rd class categories, which points to significant organic pollution and potential ecological stress. These findings indicate that while Uluabat and İznik lakes largely maintain acceptable water quality, Manyas Lake is under considerable pressure from organic inputs. The spatial patterns observed in the GIS maps and the trends illustrated in the graphs further emphasize the influence of site-specific pollution sources and highlight the need for targeted management strategies, particularly for Manyas Lake, to improve and sustain water quality.

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