SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2025
ORGANIZATION AND MANAGEMENT SERIES NO. 215

# MICROBIOLOGICAL QUALITY AND RISK ASSESSMENT OF NON-REGULATED LAKES USED FOR RECREATIONAL AND ECONOMIC PURPOSES

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**Purpose:** This study aims to assess the microbiological quality and risks associated with non-regulated lakes used for recreational and economic purposes. It highlights the potential risks these lakes pose to public health, especially in terms of waterborne diseases, due to fluctuations in water quality influenced by seasonal variations, human activities, and environmental factors. By evaluating the microbiological contamination levels of lakes that are not part of the formal monitoring system, this research seeks to fill a gap in understanding the risks posed by these bodies of water.
**Design/methodology/approach**: The research employs a combination of water sample collection and microbiological analysis to determine the contamination levels of *Enterococcus* spp. and *E. coli* in various water samples taken from a non-regulated lake (Wyspowo Lake). The study compares contamination levels in nearshore and lake center areas during different months to assess variability in water quality. Statistical analysis was performed to determine the significance of differences between sampling sites.
**Findings:** The study found that the water quality in Wyspowo Lake generally met the acceptable bathing water quality standards. However, exceedances of *Enterococcus* spp. counts were recorded, particularly for two shore samples collected in June and five collected in July. Shore samples consistently showed higher bacterial levels than samples collected from the lake center, especially for *Enterococcus* spp. These findings highlight the need for increased monitoring of non-regulated lakes to protect public health.
**Research limitations/implications**: The study is limited by seasonal sampling and the absence of continuous monitoring. Future research could involve more frequent sampling and explore the effects of local human activities on water quality.
**Practical implications:** Improved monitoring systems for non-regulated lakes are essential for protecting public health. The study suggests integrating quality and risk management strategies into local monitoring practices.
**Social implications:** The study has significant social implications as it highlights the potential health risks posed by non-regulated lakes, which are often frequented by local communities for recreational purposes. By improving water quality monitoring and public awareness, the research could contribute to better public health outcomes and foster a culture of responsible recreational use of natural resources. Additionally, it could inform local policy decisions related to water management and environmental health, ultimately enhancing the quality of life for people living near these lakes.

**Originality/value:** This article provides original insight into the microbiological quality and risk assessment of an unregulated lake. It adds value to this field by addressing the microbiological safety of lakes not covered by official regulatory systems and proposing practical solutions for improving water quality monitoring and risk management. The article is intended for local authorities, environmental health experts, and public health, water management, and environmental policy researchers
**Keywords:** quality management, risk assessment, microbiological quality, public health, non-regulated lakes.
**Category of the paper:** research paper.

# 1. Introduction

Surface water contamination is a significant global challenge, driven by both natural processes and human activities (Vadde et al., 2018). Key contributors to this issue include industrial development, agricultural practices, industrial waste from food production, surface runoff, natural events, and insufficient water supply and wastewater treatment infrastructure. The release of untreated waste into aquatic ecosystems exacerbates water pollution, leading to widespread contamination of water bodies (Lin et al., 2022; Yesilay et al., 2023). The health consequences of water pollution are complex and multifaceted. Exposure to contaminated water can lead to both short-term and long-term health issues, depending on the nature of the contaminants and the level and duration of exposure (Krishan et al., 2023).

## 1.1. Health risks and the need for effective management of recreational waters

During the swimming season, the primary risk of contracting bacterial, protozoal, and viral gastroenteritis is typically linked to contact with recreational water, rather than food consumption or drinking water. Illnesses associated with recreational water exposure are frequent, with activities such as swimming, paddling, boating, and fishing contributing significantly to annual cases of gastrointestinal, respiratory, and skin, ear, and eye infections (Sanborn, Takaro, 2013; Staley et al., 2013; Russo et al., 2020). Swimmers are estimated to ingest between 10 and 150 mL of water per hour, with children under the age of 10 being particularly vulnerable due to prolonged exposure in shallow, contaminated areas, frequent immersion of the head, and hand-to-mouth contact (Sanborn, Takaro, 2013). The identification of contamination sources and the development of effective management strategies are essential for minimizing public health risks (Lin et al., 2022). Bathing waters host numerous microorganisms, including viruses, bacteria, fungi, algae, protozoa, and their metabolic products. The abundance and species composition of these microorganisms, as well as their activity, are largely influenced by climatic and trophic conditions (Kacprzak, 2019). Swimming in contaminated beach waters significantly increases the risk of skin infections and other illnesses. Pathogenic microorganisms commonly found in polluted water are often the cause of

skin conditions in swimmers. Individuals exposed to bacterial levels above safety thresholds face a significantly higher risk of developing skin diseases. Research indicates that swimmers report skin infections 3.5 times more frequently than non-swimmers (Yau et al., 2009; Lin et al., 2022). Given the intersection of public health, environmental management, and risk management, addressing water quality issues at recreational sites is critical for protecting user health. Moreover, improving quality management practices in water safety is necessary to reduce these risks and safeguard public well-being.

### 1.2. International guidelines on water quality and risk management

International guidelines, including those from the World Health Organization (WHO) and the European Union, set water quality standards for bathing sites to protect user health through regular monitoring and risk assessment. WHO recommends systematic microbiological testing, with fecal coliforms used as indicators of fecal contamination and overall water quality (Doe et al., 2016). The EU's Bathing Water Directive (Directive 2006/7/EC) emphasizes bathing site profiling and preventive measures to reduce health risks. These guidelines provide a regulatory framework that aids in reducing public health risks through proper water quality management. Together, these standards offer a structured approach to water quality management and risk assessment, improving the overall health protection of recreational water users.

### 1.3. National water quality management and regulatory framework

The Water Law establishes a water quality management system for bathing areas aimed at enhancing the health safety of bathers and predicting potential hazards. The implementing regulations set standards for water quality monitoring, bathing area profiling, registration and signage of these areas, and outline the authority of the State Sanitary Inspectorate (Kacprzak, 2019; Zwierzyna, 2022). Waters in bathing areas are classified by the State Sanitary Inspectorate based on two microbiological parameters: *Escherichia coli* and intestinal enterococci, in accordance with the provisions of the Minister of Health's Regulation (2019).

### 1.4. Factors hydrological and ecological profile of the Wejherowo district

Wejherowo district, located in northern Kashubia, is a picturesque area positioned along a major transportation corridor connecting Gdańsk and Szczecin. Situated just a few kilometers in a straight line from the Baltic Sea, over half of the commune's area is part of the Tricity Landscape Park. The entire region falls within the catchment area of rivers flowing into the Baltic, with a well-defined hydrological network. Primary watershed boundaries divide Wejherowo into four river basins: Reda, Piaśnica, Zagórska Struga, and Gizdepka. Beyond its extensive river network, Wejherowo features several scenic lakes, mainly concentrated on the plateau of the Kashubian Lake District near the terminal moraine. These are mostly kettle lakes,

lacking surface outflow, with prominent examples including Wyspowo, Bieszkowice, Zawiat, Borowo, Pałsznik, and Wygoda. Additionally, the commune encompasses ecologically valuable areas protected under various conservation designations, such as the ecological sites "Szuwary Jeziora Wyspowskiego" and "Wyspowska Łąka", underscoring the importance of adhering to protective measures for these natural habitats. (Mieloch-Stojczyk, 2021).

### 1.5. Research problem and aim of the study

At public bathing sites, the health of individuals using water attractions should be protected through systematic water sampling and the temporary closure of sites that exceed microbial levels specified by regulations. The supervision of bathing sites and areas occasionally used for swimming, particularly regarding water quality management, falls under the responsibility of local sanitary inspectors (Zwierzyna, 2022). However, not all bathing areas are subject to regular microbiological inspections. These inspections are mandatory only at officially registered sites designated as bathing areas by local authorities, whereas sites used occasionally for swimming, lacking official status, are not systematically monitored. This lack of oversight raises a critical health risk management issue: Are users of unmonitored recreational lakes exposed to higher risks of waterborne illnesses? The aim of this study was to evaluate the microbiological safety of a recreational lake that lacks official sanitary controls, addressing the public health risks posed to users and highlighting the need for improved risk management practices in water quality supervision.

## 2. Material and Method

### 2.1. Study area

The Wyspowo Lake, located in northern Poland at the edge of the Kashubian Lake District, is a forest-enclosed lake bordered by a large meadow, southeast of Wejherowo near the village of Zbychowo in the Wejherowo commune, Pomeranian Voivodeship, within the Tricity Landscape Park (coordinates: 54°33′33″N 18°18′12″E). Encompassing an area of 23.0 hectares and bordered by a shoreline measuring 1,910 meters, Wyspowo Lake reaches a maximum depth of nearly 5 meters, with an average depth of 2.6 meters. The Cedron River flows through the lake. Primarily serving as a recreational and tourist site for residents of the nearby Small Tricity region (Wejherowo, Reda, Rumia), Wyspowo Lake is especially popular among members of the Rumia Chapter No. 50 of the Polish Angling Association. The area around the lake features seasonal cottages and the village of Wyspowo, part of the Zbychowo district. Nearby, a large forest parking area accommodates numerous camper trailers during the summer season (Jezioro Wyspowo, 2013).

### 2.2. Research materials and Microbiological analyses

The study material comprised water samples collected from Wyspowo Lake, specifically from nearshore water layers (n = 32) and the lake center (n = 32). Samples were collected in sterile containers from a depth of approximately 0.5 m below the water surface. Immediately after collection, the samples were stored in an insulated cooler at 4±1°C and transported to the laboratory within 2 hours for analysis. Each analysis was performed in four replicates to ensure accuracy and reliability of the results. The traditional plate count method was used for microbiological assays. Sampling procedures followed the Water Law Act of 20 July 2017 (Journal of Laws of 2021, item 624, as amended), which defines the bathing season from 1 June to 30 September. In accordance with the Regulation of the Minister of Health of 17 January 2019 on water quality supervision in bathing and occasionally used bathing sites (Journal of Laws of 2019, item 255), each water sample was analyzed for *Escherichia coli* and *Enterococcus spp.* counts.

Microbiological tests were carried out to determine the number of:

- *Escherichia coli* on Coli ID medium from bioMerieux (incubation at 37°C for 48 h),
- *Enterococcus* spp. on D-coccosel medium from bioMerieux (incubation at 37°C for 48 h).

### 2.3. Statistical analysis

The normality of the samples was checked using the Shapiro-Wilk test. Differences between groups in bacterial counts for water samples taken from different locations (lake shore and lake center) were tested using the Mann-Whitney U test. The significance level was set at 0.05. The data were processed using Statistica software (StatSoft, Inc.).

## 3. Results and Discussions

In 2023, the Wejherowo district hosted two designated bathing areas: Lake Wysoka - Wycztok in Kamień and the Lubiatowo Sea Bathing Area located between beach entrances 43 and 44. Additionally, there were four occasional bathing sites organized at scout camps and one publicly accessible occasional bathing area at Lake Zawiat in Bieszkowice. At the Wysoka – Wycztok bathing area, a temporary bloom of blue-green algae was observed at the end of the summer season, while Lake Zawiat experienced a temporary bacteriological contamination before the start of the bathing season. In response to these identified issues and to protect public health, the State District Sanitary Inspector in Wejherowo implemented a temporary bathing ban at these bathing sites until water quality improved (Informacja o stanie..., 2024). Similarly, the analysis of water samples from Wyspowo Lake, which included samples from both

nearshore and lake center locations, revealed that while average microbiological contamination of the water met the required standards for bathing water quality (≤1000 and ≤400 CFU/ 100 mL, respectively), as outlined in the Journal of Laws (2019, item 255), exceedances of the permissible *Enterococcus* spp. count were detected in several samples. These exceedances suggest that the water quality in some areas of the lake may be compromised due to ongoing or episodic sources of contamination. Heavy rainfall in July may increase fecal coliform and enterococci levels, as stormwater runoff introduces fecal-origin bacteria into water bodies, worsening contamination (Staley et al., 2013). Specifically, two shore samples collected in June and five samples collected in July exceeded the permissible limits for *Enterococcus* spp. The highest concentration of Enterococcus spp. recorded was 1200 CFU/100 mL, which is three times the allowable limit, suggesting the potential for long-standing fecal contamination of the water (Stec et al., 2022). No samples exceeded the permissible *E. coli* levels, though one sample collected from the shore in September contained *E. coli* at 800 CFU/100 mL. These results highlight the variability in water quality during different times of the year, especially during months when fewer bathers were present. Although no statistically significant difference was found between the sampling sites (shore vs. lake center) and *E. coli* counts ($z = 1.44$; $p = 0.1507$), a noticeable increase in *E. coli* levels—approximately 50% higher—was observed in the samples collected from the shore (Table 1). However, a statistically significant difference was found between shore and lake center samples regarding *Enterococcus* spp. counts ($z = 2.88$, $p = 0.0040$).

**Table 1.**
*Average microbial content depending on sampling location [cfu/100mL]*

| Kind of bacteria | Lake shore (LS) n = 32 | | Center of the lake (CL) n = 32 | | Z | *p* |
|---|---|---|---|---|---|---|
| | M | SD | M | SD | | |
| *E.coli* | 178.1 | 171.8 | 115.6 | 88.4 | 1.44 | 0.1507 |
| *Enterococcus* | 246.9 | 256.6 | 93.7 | 66.9 | 2.88 | 0.0040 |

M - Mean; SD – standard deviation; z (with correction): value of the Mann-Whitney U test statistic with correction; p - significance level.

Source: own studies.

The literature confirms that nearshore waters are typically the most contaminated (Pandey, et al., 2014), as evidenced by the results of this study (Table 1). People bathing in these areas, especially children, are at increased risk of gastrointestinal illness, as they often spend extended periods in the water, playing both in the water and on the sand (Sanborn, Takaro, 2013). According to the World Health Organization, over 50% of deaths caused by water-related diseases are due to bacterial intestinal infections (Lin et al., 2022; Stec et al., 2022). In comparison to July and August, some of the water samples collected in June and September were free from the examined bacteria, which may be attributed to the lower number of bathers during these off-peak months. The risk of illness is determined by both the concentration of pathogens in the water and the level of human interaction with it. Activities that involve close

contact with water, such as swimming or bathing, carry a higher risk compared to those with limited exposure. Water quality standards are primarily established to protect public health during such high-contact recreational activities (Russo et al., 2020; Guidelines on recreational…, 2021). Integrating quality management and risk management principles into monitoring and control systems can enhance the effectiveness of these guidelines, ensuring consistent protection of public health and minimizing exposure to harmful pathogens. Wyspowo Lake, while surrounded by forest and adjacent to a meadow, is also in proximity to seasonal summer cottages and a large forest parking lot that accommodates numerous camping trailers during the summer months. These human activities contribute to the vulnerability of surface waters, which are prone to rapid and significant microbiological quality changes. Such fluctuations often stem from municipal wastewater discharge, agricultural runoff, and rainwater carrying pollutants into water bodies like lakes and rivers, posing risks to their ecological balance and public health (Staley et al., 2013; Stec et al., 2022). Given the increasing risk of microbiological contamination in lakes not covered by the sanitary-epidemiological supervision system, there is an urgent need for regular water quality monitoring in these water bodies. Monitoring such lakes is crucial, especially when they are used for recreational and economic purposes, as it allows for early identification of potential health risks and the implementation of appropriate preventive measures

## 4. Summary and Conclusions

Based on the findings of this study, it is evident that lakes not covered by the formal monitoring system can still pose significant microbiological risks, especially when used for recreational and economic purposes. Variations in water quality, influenced by seasonal factors, human activities, and environmental conditions, were observed. Despite compliance with regulatory limits on average, exceedances of fecal indicator bacteria, such as *Enterococcus* spp., were detected, particularly in shore samples during months with higher rainfall and increased stormwater runoff. This highlights the importance of monitoring non-regulated lakes to ensure public health safety and mitigate the potential risks of waterborne diseases. Effective integration of quality management and risk management strategies into water quality monitoring systems is essential to protect the health of individuals engaging in recreational activities, particularly in high-contact areas such as nearshore waters. Further research and regular surveillance of these water bodies are crucial to maintaining water safety standards and minimizing public health risks.

## Acknowledgements

The research was financed via the funds allocated to the UMG departments for research activities under project number WZNJ/2024/PZ/01.

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