Safety of water for human consumption: a case study from Northern Italy

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ABSTRACT

Water is essential for health, and climate change can compromise its quality. The Local Brianza Health Protection Agency (ATS) has initiated a biennial monitoring project of water supply sources to ensure safe and clean water access, in line with the United Nations (UN) Agenda 2030. The project has identified vulnerabilities in the water supply chain, finding the presence of cyanobacteria in 19.7% of samples. Risk assessment results show that climatic conditions could influence the vulnerability of sources.

Introduction

Water is a fundamental determinant of health and one of the most vulnerable elements of our planet with regard to the ongoing climate changes. The impact of these changes on the availability, quality, and hygienic safety of water resources is well documented. The United Nations (UN) recognizes water as a universal human right, a principle reiterated in the Drinking Water Directive (2020/2184) issued by the European Union in December 2020 and subsequently transposed into Italian law through the Legislative Decree (LD) 18/2023 (LD, 2023). Based on these considerations, the Department of Hygiene and Health Prevention of the Local Brianza Health Protection Agency (ATS) has initiated a comprehensive monitoring program on the most at-risk water supply points. This initiative aimed at enhancing the effectiveness, efficiency, and appropriateness of policies in place within ATS Brianza that protect the safety of water intended for human consumption. This project engages with the challenge posed by the UN Agenda 2030 in ensuring universal access to drinking water, reducing the release of pollutants and harmful substances, including emerging contaminants, while exploiting a risk-based approach through the drafting of a Water Safety Plan (WSP) (Lucentini *et al*., 2014).

The investigation was conducted during the period 2022-2023 on potable waters in the Provinces of Lecco and Monza Brianza. The specific objectives were to identify and assess sources of vulnerability and quantify the risk of contamination of supply sources from: i) cyanobacteria and their toxins, with particular attention to the class of microcystins; ii) viruses such as bacteriophages, the subgroup of somatic coliphages; iii) spore-forming bacteria particularly resistant to treatment processes such as *Clostridium perfringens*, as well as the classic indicators of fecal contamination (*Escherichia* coli and Enterococci) in water supply sources near surface water bodies.

In the province of Lecco, water distribution for human consumption is managed by Lario Reti Holding SPA, with the primary water supply system being the Intermunicipal Aqueduct Brianteo. This system includes a sole lake water intake which, through auxiliary works and connections to local networks, directly serves 64 municipalities across the provinces of Lecco, Como, and Monza. The Brianteo water treatment system originates from the facility located at the end of the Lecco branch of Lake Como. It extracts and treats lake water at a rate ranging from 500 to 1,100 liters per second. Additional water sources in the Lecco province include numerous springs and wells, some situated near water basins and others adjacent to the Adda River's bed.

The water provided by Lario Reti Holding exhibits varying characteristics across different municipalities, but can be gener-

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ally classified into four main types, based on geographic origin and hydrogeological criteria: i) water from springs in the pre-Alpine area north of the Orobic Line (Alpine metamorphic rocks); ii) water from springs in the pre-Alpine area south of the Orobic Line (pre-Alpine sedimentary rocks); iii) water from wells in the hills and plain areas; iv) water from the inter-municipal aqueduct.

Materials and Methods

The 61 monitored points have been distributed across 31 types of facilities, including wells and springs. Of these, 14 facilities are located at Lake Como, 9 along the River Adda, 4 at Lake Annone, and 2 at Lake Bosisio.

For every 61 study sites, 11.5 L of water were collected, including: i) 0.5 L for physicochemical analyses (pH, conductivity, and THMs Trihalomethanes), following Ottaviani and Bonadonna (2007) and the limits specified in LD (2023); ii) 1 L in sterile containers for microbiological analyses (methods and limits according to LD (2023) and for somatic coliphages (method and limits according to UNI EN (2001) and LD (2023), respectively); iii) 10 L in dark containers; 5 L were used for microscopic counting and identification of cyanobacteria according to UNI EN (2006), and the remaining 5 L were concentrated to a ratio of 1:500 by filtration with nylon membrane (pore size 1.2 µm) and used for Microcystin (MSs) and Nodularin (NOD) detection through ELISA testing, following the limits outlined in LD (2023).

The risk of vulnerability was calculated by assigning a score of 0 for samples that tested negative for all parameters over the two-year period; a score of 1 for each positive parameter, except for the presence of cyanobacteria or microcystins, which were assigned a score of 2 for every year of positivity. The partial scores were summed, and based on the values obtained, three risk ranges were hypothesised: low 0-1; medium 2-3; high >3.

Results and Discussion

The analytical results obtained in 2022 and 2023 are shown in Figure 1. Regarding cyanobacteria, 14.9% and 9.1% of the sampling points tested positive in 2022 and 2023, respectively. The most common species in the two years were *Planktothrix* (with the highest density of 170,000 cells L^{-1} In Malgrate well after treatment) and *Pseudanabaena*. Cyanotoxins (MCs and NOD) concentrations were <0.15 µg L^{-1} in all cases.

Regarding the other microbiological parameters examined, positive results were found for *Clostridium perfringens* (8.3% positivity in 2022 and 1.8% in 2023), *Escherichia coli,* and Enterococci, each not examined in 2022 and with 15% positivity in 2023. The highest frequency of positivity was for somatic col-

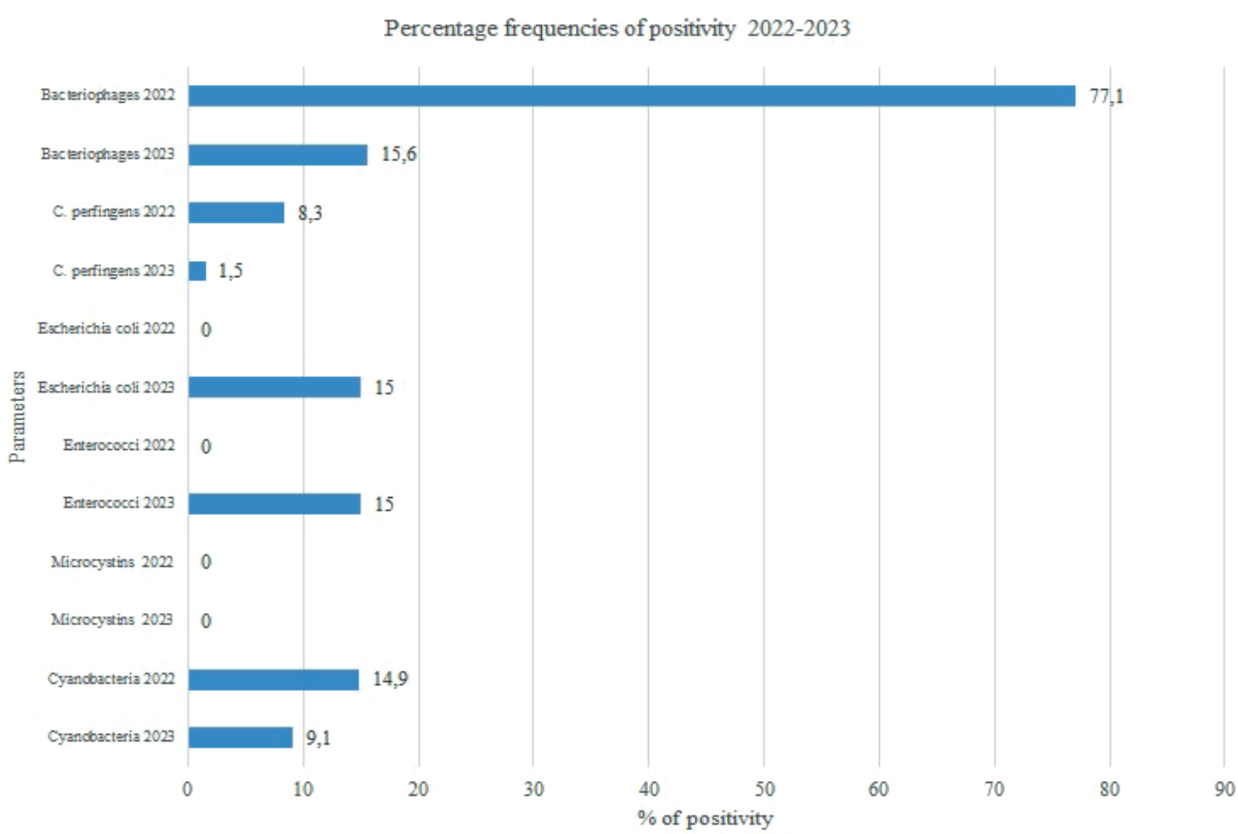

Figure 1. Monitoring results. The bars show the percentages of positivity for pathogenic bacteria, cyanobacteria and cyanotoxins out of the total number of samples analysed.

iphages, which were detected in 70% and 15% of the points analyzed in 2022 and 2023, respectively.

The trends in positivity rates may suggest that vulnerability could be influenced by meteoclimatic conditions (not explicitly considered in this work), which in turn lead to significant variations in the flow of the main reservoirs and consequently of secondary ones. Monitoring campaigns were conducted from June to September: in 2022, precipitations were very scarce, while in 2023, the situation was the opposite, with abundant rainfall in both provinces.

Two sampling points in Giussano and Besana Brianza (MB), approximately 20 km far from Lake Como, tested positive for bacteriophages and cyanobacteria in both years. The source of contamination remains unclear, particularly regarding the cyanobacterium *Planktothrix rubescens*. Two possible explanations warrant further investigation, including a malfunction of the Brianteo water treatment plant that may have allowed cyanobacteria to enter the water network from the water column above the intake where they are normally present; cyanobacteria then adapted to survive even in the absence of light by activating a heterotrophic metabolism (Perez-Garcia *et al*., 2011). Alternatively, hydrogeological continuity with the main water body may have caused the contamination of the well.

The analysis of the data allowed an assessment of the vulnerability at the investigated supply points (Table 1). In particular, 24.6% of the points monitored over the two-year period showed a high level of criticality, with 60% (7 high-risk points out of 15) attributed to the presence of cyanobacteria. In collaboration with the water management authority, a monitoring frequency has been established based on vulnerability: i) twice a year for critical points (24.6%); ii) annually for moderately critical points (11.5%); iii) every two years for low vulnerability points (63.9%).

Given the nature of the waters in the investigated territory, it was deemed important to study the cyanobacteria density, as it represents a useful indicator for assessing the quality of water intended for human consumption. Excessive cyanobacterial biomass, in addition to the inconveniences caused by the production of foul-smelling substances (Bowmer *et al*.,1992), has significant negative consequences for aquatic resources utilization due to the risk associated with the production and release of toxic compounds (cyanotoxins), which may also transfer along trophic and food chains. The definition and quantitative assessment of risk depend on the autecology of the dominant cyanobacterial species (Cerasino *et al*., 2012; Chorus *et al*., 2021), including the dynamics of bloom formation, the presence of toxic strains, types of toxins produced, and the intended use and the corresponding aqueduct system.

Acute or short-term effects associated with the consumption of contaminated water may arise from inefficient water treatment processes in the removal of cyanobacteria and cyanotoxins. Significant levels of cyanotoxins in raw water may result from both natural cellular lysis consequent to bloom senescence and artificial lysis due to inappropriate purification treatments. Studies on the impact of these pollutants on human health are still limited, primarily due to challenges in establishing a temporal link adequate to demonstrate cause-effect associations. The few documented cases concern incidents that occurred in Brazil, Australia, and the US (Metcalf *et al*., 2012). In industrialized countries, where drinking water is strictly controlled, chronic exposure remains the most likely risk, with the cause-effect relationship being particularly challenging to demonstrate from an epidemiological perspective (Svircev *et al.*, 2009).

Table 1. Summary of risk assessment findings.

	Risk assessment			
	Low	**Medium**	**High**	**Total**
N°	39	7	15	61
%	63,9	11,5	24,6	
Monitoring frequency	Biennial	Annual	Half yearly	

Conclusions

The monitoring data showed considerable variability between sampling points in the concentration of cyanobacteria, colony-forming units of bacteria, and plaque-forming units of viruses.

The project has allowed for an in-depth understanding of water supply sources and their associated vulnerabilities, but does not allow for conclusions to be drawn regarding the causes of the variability in the analytical data obtained. It will therefore be necessary to collect further experimental data that will enable a statistical analysis of the potential impact of weather variability on water quality, and to conduct a hydrogeological study to explore the interconnections between the supply sources and the main reservoirs.

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