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Water quality in reservoirs: environmental implications of cyanobacterial contamination on public health in Brazil

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Abstract: Cyanobacteria are important for the functioning of the ecosystem. However, the intensification of the eutrophication process in waters leads to an increase in the intensity and frequency of blooms, as well as the production of cyanotoxins. Starting with the question: Which cyanobacteria have the highest incidence in contaminated reservoirs in Brazil? Following the hypothesis that if the presence of some cyanobacteria contributes to the contamination of reservoir waters, then these species have cyanotoxins. The aim was to carry out a bibliographic analysis of the cyanobacteria responsible for the contamination of reservoir waters and the environmental implications for public health. The literature survey used the scientific databases PubMed and Scielo, defining the periodicity from 2018 to 2022. A taxonomic classification of cyanobacteria species was carried out, with 9 articles referring to the contamination of reservoir waters in the Northeast, South and Southeast regions. The cyanobacteria that form the most recurrent blooms in reservoirs in Brazil belong to the order Nostocales and Chroococcales. Climatic seasonality plays a decisive role in the spatio-temporal dynamics of cyanobacteria, with higher concentrations occurring in the dry season and worsening water quality during the bloom. Monitoring is therefore essential to avoid environmental implications.

Key words: environment; cyanobacteria; health; water; contamination

1 Introduction

Cyanobacteria are prokaryotic organisms that have the properties of both algae and bacteria [1]. They are important for the functioning of the ecosystem, however, the growing eutrophication of aquatic environments can affect the biome as a whole, causing the ecosystem to lose its service functions, thus favoring the production of cyanotoxins that threaten ecological and human health [2].

Water safety and quality are important issues for agriculture, animals and human health [3]. However, the urbanization of watersheds contributes to the degradation of water bodies [4], associated with anthropogenic action and water pollution from industrial activities, agriculture and the lack of basic sanitation [5].

In Brazil, almost half of the population does not have access to sewage collection and treatment and untreated effluents generate cyanobacterial blooms [4]. These blooms cause serious environmental implications, including unpleasant odors and the production of cyanotoxins [6].

Increased concentrations of toxins in water from supply reservoirs exposes the population to serious risks, since they are not removed by conventional treatment or filtration [7], such as the consumption of unsuitable water, especially when there is an occurrence of HABs (Harmful Algae Blooms), a cyanobacterium that causes various human health problems [8].

Some of the genera considered potentially toxic are Microcystis, Planktothrix and Aphanocapsa [1]. Microcystis aeruginosa is a species of cyanobacterium with frequent records in bloom events in the country and is related to the formation of unwanted halogenated organic by-products [9].

Demographic changes associated with the complexity of contemporary environmental problems, such as global environmental change and technological disasters, as well as human-induced climate change [10], have been a growing concern in recent years, causing negative environmental impacts [11].

Cyanotoxins have been reported as lethal agents for living beings and can harm animals, people, aquatic species, recreational activities and drinking water reservoirs [6]. It is therefore necessary to establish parameters that make it possible to diagnose whether the ecosystem is deteriorating [12].

This intensification of the eutrophication process in surface waters leads to an increase in the intensity and frequency of cyanobacterial blooms, compromising water availability for consumptive use [13], a state of altered water quality, including increased pH, stratification and lower water transparency [14]. There is a characteristic pattern of seasonality in algal blooms and cyanobacterial communities [7].

Thus, knowing the ecological changes in a reservoir is of great importance for environmental impact studies and water quality assessments [15], demonstrating that biodiversity losses reduce the functioning of the ecosystem [14]. Especially in arid and semi-arid regions, where water scarcity and the increased demand for water for multiple uses have encouraged the construction of various reservoirs and water transfer systems, despite the fact that these measures provide quantitative solutions, the supply of available water quality can become an obstacle [16].

Based on the question: What are the cyanobacteria with the highest incidences in contaminated reservoirs in Brazil? Following the hypothesis that if the presence of some cyanobacteria contributes to the contamination of reservoir waters, then these species have cyanotoxins. The aim was to carry out a bibliographical analysis of the cyanobacteria responsible for the contamination of reservoir waters and the environmental implications for public health.

2 Methodology

Once the research topic had been delimited, an investigation was carried out, following the methodologies of a systematic review of the literature of a descriptive nature [17], based on the search with the combination of the descriptors environment , cyanobacteria , public health , contaminated water , environmental impacts , in online searches, selecting as sub-areas of interest, and/or terms and synonyms found in the literature.

The scientific databases Scientific Electronic Library Online (SciELO) and Medical Literature Analysis and Retrieval System online (MEDLINE via PubMed) were used for the literature survey. The database screening was carried out between January 17, 2023 and February 5, 2023 (Figure 1).

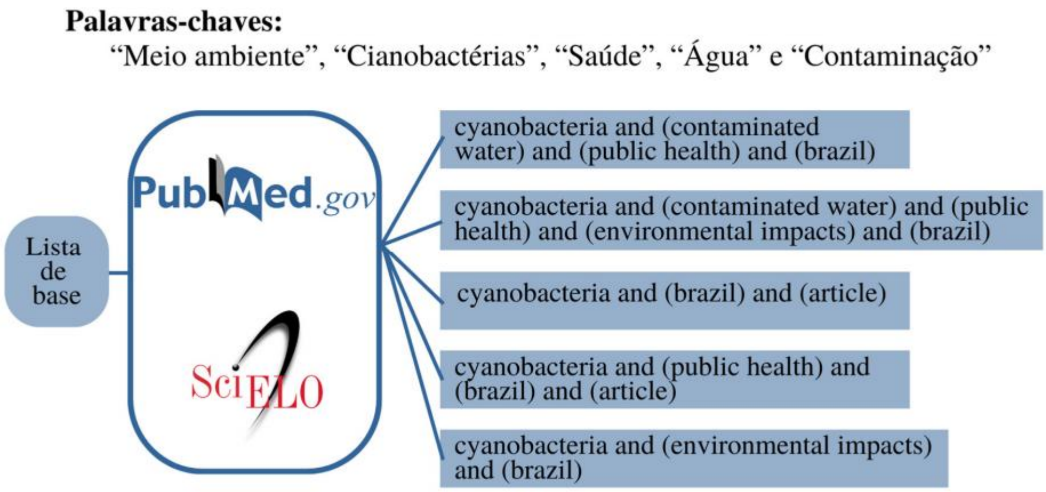

Figure 1. Descriptors and terms used to search for scientific studies in the list of databases

Source: Authors, 2023.

Among the selected references, filters available on the platforms themselves were used as classification criteria, defining the periodicity of 5 years, from 2018 to 2022 for publications only articles with translation in English and Portuguese, also selecting the parameter "research article", excluding "review articles" and "books and encyclopedias".

The research was carried out by analyzing the articles found in three stages. Initially, all the titles of the articles found in the databases with the descriptors used were read, selecting those with terms related to cyanobacteria in reservoir water. Once the articles had been selected, the second stage involved reading the abstracts. Articles that met the inclusion criteria were selected for the third stage, i.e. those that mentioned some information about identifying the species of cyanobacteria found in reservoir water. Finally, in the third and last stage of the study, the full texts of the articles selected in the second stage were read and evaluated in order to explore the information in the studies and conclude the objectives of this review, this analysis being qualitative, where the main data from the articles chosen was extracted [17]. A taxonomic classification of the cyanobacteria species found was carried out at genus, family and order level, according to the specialized literature, which was presented in figure form.

According to the topic selected for this study, studies that deviated from the inclusion criteria were excluded and articles with incomplete, inconsistent or duplicated content were not included in the literature survey.

3 Results and discussion

3.1 Database selection

From a search for articles on cyanobacteria responsible for contaminating reservoir water and their environmental implications for public health, 541 articles were found in the selected databases. After removing the documents based on the inclusion criteria, this review totaled 44 articles evaluated by title and abstract. This resulted in 11 articles for full analysis (Figure 2). Of the articles selected, 9 referred to the contamination of reservoir water by cyanobacteria.

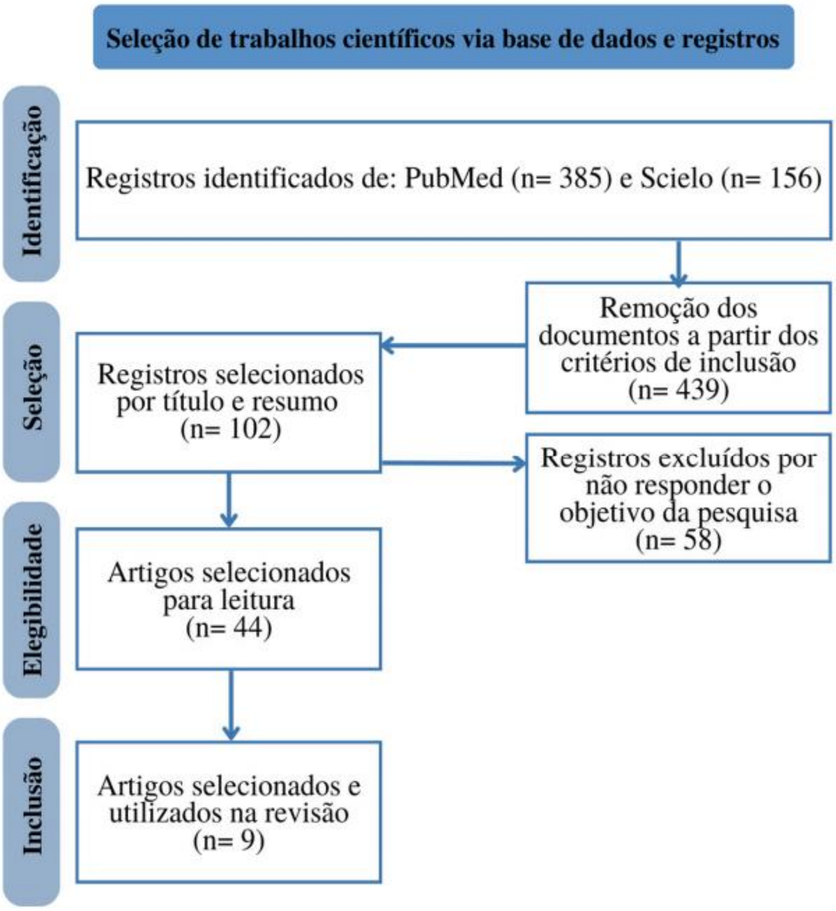

Figure 2. Flowchart for searching and selecting scientific papers

Source: Authors, 2023.

3.2 Reservoir water contaminated by cyanobacteria

Of the 9 articles on water contamination in reservoirs, 5 were in the Northeast in 2018, 2021 and 2022; 2 in the Southeast in 2018 and 2022 and 2 in the South in 2018.

3.2.1 Northeast region

The most recurrent bloom-forming cyanobacteria in reservoirs in the Northeast region of Brazil belong to the order Nostocales and Chroococcales, and mainly to the species Microcystis aeruginosa (Figure 3), which is dominant and increases its biomass in the presence of zooplankton [16][18].

The functional structure of the phytoplankton community in these reservoirs is influenced by the increase in temperature and nutritional enrichment in different ways over the seasons [19]. These interactions between phytoplankton and zooplankton further highlight the importance of the role of zooplankton in promoting the growth of cyanobacteria and maintaining the proliferation of algae [18].

Climate seasonality plays a decisive role in the spatio-temporal dynamics of cyanobacteria, which occur in higher concentrations during the dry season [13]. With the reduction in the volume of water in the reservoirs and the extreme drought conditions in this region, these conditions influence the composition and biovolume of the phytoplankton and the quality of the water [20]. This worsening in water quality shows an increase in the concentrations of potentially toxic cyanobacteria, as well as other parameters that measure water characteristics [16].

3.2.2 Southeast region

In the southeastern region of Brazil, the frequency of cyanobacterial blooms of the order Nostocales (Figure 3) was evident, with the occurrence of the Aphanizomenon family being related to adaptive advantages in eutrophicated environments [21], as well as the production of cyanotoxins that cause ecological and public health concerns [22].

This sanitary issue in reservoirs compromises the original characteristics of the water due to the dense presence of potentially toxic species, indicating that the multiple uses of the reservoir are compromised [21]. And from an ecotoxicological point of view, the risk quotients for the estimated values of the cyanotoxins microcystins and saxitoxins greater than 1 indicate a high risk for aquatic life [22].

3.2.3 Southern region

In the southern region of the country, the order Chroococcales and the family Microcystaceae represented the most common cyanobacteria in these reservoirs (Figure 3).

The predominance of cyanobacteria in reservoirs indicates that the environment is undergoing an intense process of environmental degradation, threatening the integrity of biological communities and causing significant damage to the ecosystem as a whole [15]. The impairment of water quality during the bloom in this region occurs annually during the summer and fall months, and the low level in the reservoirs and the higher sunshine temperatures are factors involved in the bloom, requiring additional use of chemical inputs in water treatment, corresponding to a cost increase of up to 58% [23].

Autor/ Ano	Região brasileira	Espécie Cyanobacteria	Gênero	Família	Ordem
Souza, Crossetti, Becker (2018)	Nordeste	*Aphanizomenon gracile*	*Aphanizomenon*	*Aphanizomenonaceae*	*Nostocales*
		Microcystis aeruginosa	*Microcystis*	*Microcystaceae*	*Chroococcales*
Severiano, Amaral, Diniz e Moura (2021)	Nordeste	*Cyclotella meneghiniana*	*Cyclotella*	*Stephanodiscaceae*	*Thalassiosirales*
		Raphidiopsis raciborskii	*Raphidiopsis*	*Nostocaceae*	*Nostocales*
		Microcystis aeruginosa	*Microcystis*	*Microcystaceae*	*Chroococcales*
Lima e colaboradores (2022)	Nordeste	*Aphanocapsa spp.*	*Aphanocapsa*	*Microcystaceae*	*Chroococcales*
		Cylindrospermopsis sp.	*Cylindrospermopsis*	*Nostocaceae*	*Nostocales*
		Geitlerinema sp.	*Geitlerinema*	*Geitlerinemataceae*	*Geitlerinematales*
Rego, Rangel-Junior, Costa (2022)	Nordeste	*Planktothrix agardhii*	*Planktothrix*	*Phormidiaceae*	*Oscillatoriales*
		Microcystis aeruginosa	*Microcystis*	*Microcystaceae*	*Chroococcales*
		Anabaena planktonica	*Anabaena*	*Aphanizomenonaceae*	*Nostocales*
		Anabaena spp.	*Anabaena*	*Aphanizomenonaceae*	*Nostocales*
		Cylindrospermopsis raciborskii	*Cylindrospermopsis*	*Nostocaceae*	*Nostocales*
França e colaboradores (2022)	Nordeste	*Oscillatoria sp.*	*Oscillatoria*	*Oscillatoriaceae*	*Nostocales*
		Microcystis sp.	*Microcystis*	*Microcystaceae*	*Chroococcales*
		Merismopedia sp.	*Merismopedia*	*Microcystaceae*	*Chroococcales*
		Cylindrospermopsis sp.	*Cylindrospermopsis*	*Nostocaceae*	*Nostocales*
		Pseudanabaena sp.	*Pseudanabaena*	*Pseudanabaenaceae*	*Pseudanabaenales*
		Anabaena sp.	*Anabaena*	*Aphanizomenonaceae*	*Nostocales*
		Aphanizomenon sp.	*Aphanizomenon*	*Aphanizomenonaceae*	*Nostocales*
		Aphanocapsa sp.	*Aphanocapsa*	*Microcystaceae*	*Chroococcales*
Vicentin, Rodrigues, Moschini-Carlos, Pompêo (2018)	Sudeste	*Aphanizomenon gracile*	*Aphanizomenon*	*Aphanizomenonaceae*	*Nostocales*
Passos e colaboradores (2022)	Sudeste	*Microcystis panniformes*	*Microcystis*	*Microcystaceae*	*Chroococcales*
		Raphidiopsis raciborskii	*Raphidiopsis*	*Nostocaceae*	*Nostocales*
		Dolichospermum sp.	*Dolichospermum*	*Aphanizomenonaceae*	*Nostocales*
Adloff, Bem, Reichert, Azevedo (2018)	Sul	*Microcystis aeruginosa*	*Microcystis*	*Microcystaceae*	*Chroococcales*
		Sphaerocavum brasiliense	*Sphaerocavum*	*Microcystaceae*	*Chroococcales*
Beló, Mathias, Gontarski (2018)	Sul	*Cylindrospermopsis sp.*	*Cylindrospermopsis*	*Nostocaceae*	*Nostocales*

Figure 3. Taxonomic classification of bloom-forming cyanobacteria in the Northeast, Southeast and South regions of Brazil in the last 5 years (2018- 2022) Source: Authors, 2023.

The hypothesis that if there are some cyanobacteria that contribute to the contamination of reservoir waters, it is due to the presence of cyanotoxins, answering the question of what these cyanobacteria are.

4 Conclusion

The data obtained allow us to conclude that so far, in accordance with the taxonomic names found, the waters of reservoirs in the northeast, south and southeast regions of this study are contaminated, mainly by cyanobacteria of the order

Nostocales and Chroococcales.

In addition, the articles reviewed here have shown that untreated water can lead to the occurrence of eutrophication in aquatic environments, even more so in water reservoirs used for water supply, which are also subject to the appearance of cyanobacterial blooms, a fact that leads to an increase in the proliferation of cyanotoxins, affecting public health. This makes it essential to monitor water quality conditions and the seasonal climate in the regions, thus avoiding environmental implications.

Conflicts of interest

The author declares no conflicts of interest regarding the publication of this paper.

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