Toxic Cyanobacteria and Cyanotoxins RISKs in Mainland Portugal: Insights from Published Data and Climate Change Trends

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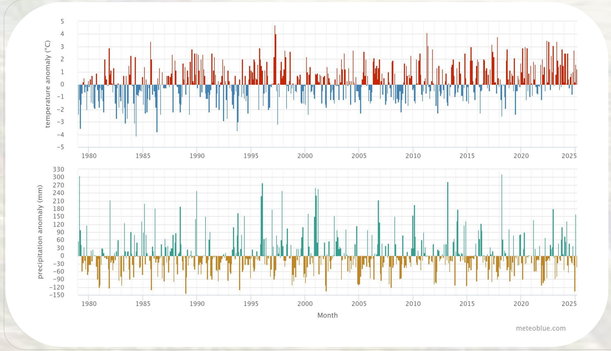
(1) Introduction

- **Eutrophication** is the nutrient-induced enrichment of aquatic ecosystems that leads to excessive phytoplankton growth, promoting the dominance of toxin-producing **cyanobacteria**.
- **Cyanotoxins**, produced by cyanobacteria, pose a significant risk to human, animal, and ecosystem health.
- These toxins exhibit organ-specific toxicity and are categorized as hepatotoxins (***microcystins, nodularins***), neurotoxins (***anatoxins***, ***saxitoxins***), and cytotoxins (***cylindrospermopsin***).

(2) Main Goals

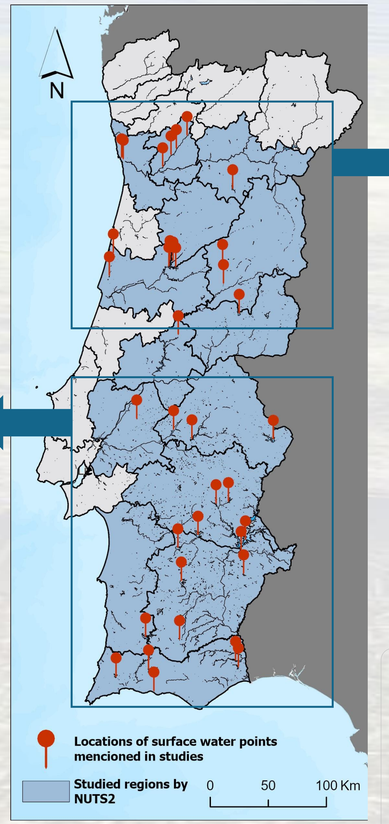
- This review compiles existing research in mainland Portugal, divided by NUTS II regions, to identify patterns, assess risks under climate change, and highlight knowledge gaps.



(3) Monthly Temperature and Precipitation Anomalies - Climate Change Portugal

- Temperature increases from north to south, showing an inverse pattern to precipitation.
- Extreme climatic events have triggered blooms, suggesting a link to **climate change**.
- **Blooms** have been detected in colder months, indicating that blooms can occur beyond spring and summer.

(4) Areas in Portugal documented in studies



(4.1) North and Center

1994 - 2007

- ***M. aeruginosa***, and ***Aphanizomenon flos-aquae*** were predominat in the center region.

2009

- ***Anatoxin-a*** was produced in a laboratory but not detected in the water samples.

2012

- First detection of **CYN** (ranging from 1.4 to **12** µg/L.) in the Center, linked to *Aphanizomenon ovalisporum.*

2012 - 2017

- ***M. aeruginosa*** dominated all samples (n=105) from the north to the center.

2022

- ***R. raciborskii*** and ***Planktothrix agardhii*** were detected in the North of Portugal, with MCs ranging from 0.3 to **18.8** µg/L.

(4.2) Alentejo and Algarve

1996

- ***Aphanizomenon flos-aquae*** exhibits higher **toxicity** compared to its American counterparts.

1999

- Four ***R. raciborskii*** strains from Alentejo showed an unknown toxic profile.

2005 - 2006

- ***M. aeruginosa***, ***Aphanizomenon spp.***, ***Planktothrix spp***. were predominant.

2000 – 2008

- Wastewater input enhanced in high **cyanobacterial densities**: *Oscillatoria sp. M. aeruginosa* and *Aphanizomenon sp.*.

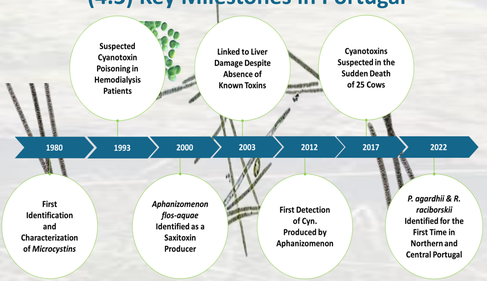
2010

- Lezíria do Tejo reservoirs had peak MCs of **506** µg/L, while A8 reached **389** µg/L.

2017

- Persistent blooms were dominated by toxic genera: ***Aphanizomenon***, ***Raphidiopsis***, ***Microcystis***, ***Oscillatoria***, and ***Planktothrix***.

(4.3) Key Milestones in Portugal



(5) FINAL CONSIDERATIONS

Cyanobacteria and cyanotoxins have increasingly spread in Portugal in recent decades. Rising temperatures, droughts, reduced precipitation, and water demand are altering aquatic ecosystems and favoring cyanobacteria. The construction of reservoirs, especially in the south, has disrupted river flow and created a lentic condition that favors bloom formation. In the North and Center of Portugal, *Microcystis aeruginosa* remains the most abundant species, particularly in warm years. The emergence of new toxic species in northern waters raises concerns about their adaptation, potentially driven by climate change. Monitoring efforts and legislation need to be revised to account for emerging toxins such as CYN, anatoxins, and saxitoxins, not only in drinking water but also in other water sources. Finally, there's the need for more data on the distribution and toxicity of less studied cyanobacterial genera and in regions without information, and the long-term effects of climate change on cyanobacterial.

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