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Distribution, driving forces, and risk assessment of 2-MIB and its producer in a drinking water source-oriented shallow lake

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Objectives

Shallow lakes are the richest freshwater ecosystems on earth. Odorants such as 2-MIB affect the safety of drinking water.Filamentous cyanobacteria, such as *Oscillatoria sp., Planktothrix sp., Pseudanabaena sp., and Aphanizomenon sp.*, are typical 2-MIB producers.Here, a shallow lake serving as an important drinking water source for Suzhou and Shanghai was selected as the study object.

Methods

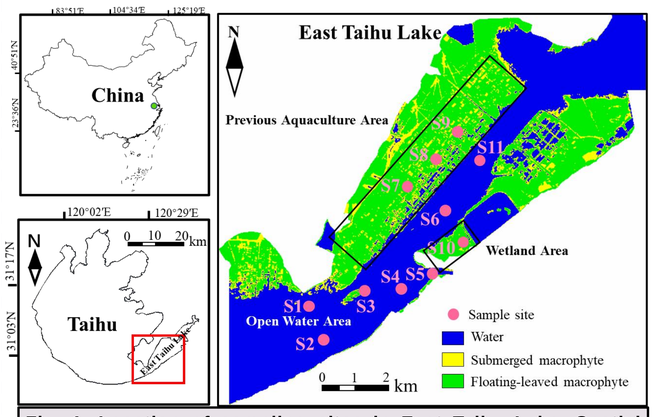

Fig. 1. Location of sampling sites in East Taihu Lake. Spatial distribution map of aquatic vegetation was obtained in August 2019 (Landsat image processed by support vector machines method, generating an overall accuracy of 97.0%)

Routine data collected on water quality, the algae community, and 2-MIB dynamics from August 2020 to November 2021 were used to identify 2-MIB producer(s), determine the driving factors of the producer, evaluate the risk of 2-MIB occurrence, and uncover the underlying mechanisms of 2-MIB increase. Specifically, 2-MIB, radiant intensity, and air temperature were daily monitored from July to October 2021 at the S4.

Results and Discussion

Water quality characteristics

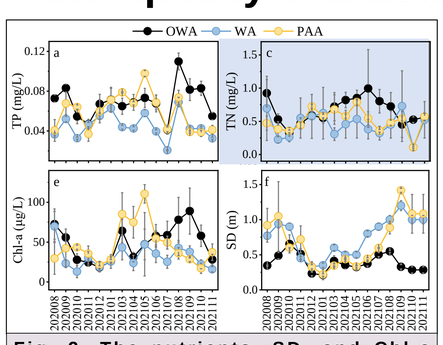

Fig. 2. The nutrients, SD, and Chl-a concentration in different parts of East Taihu Lake. (a) TP, (b) TDP, (c) TN, (d) TDN, € Chl-a, and (f) SD. OWA = open water area, WA = wetland area, PAA = previous aquaculture area

	OWA	WA	PAA
WD (m)	1.96 ± 0.^{a}	1.22 ± 0.30^{b}	1.41 ± 0.33^{a}
WT(°C)	20.7 ± 7.4^{a}	21.3 ± 7.3^{a}	21 ± 6.7^{a}
EC(μs/cm)	321 ± 65.5^{a}	334 ± 59^{ab}	352.2 ± 58.9^{b}
pH	7.84 ± 0.60^{a}	7.76 ± 0.40^{a}	7.82 ± 0.47^{a}
TSS(mg/L)	32.5 ± 15.1^{a}	13.7 ± 14.1^{b}	19 ± 14.2^{b}
DO(mg/L)	9.2 ± 1.5^{a}	7 ± 2.3^{b}	7.6 ± 2.7^{b}
Turbidity(NTU)	49.2 ± 36.1^{a}	18.5 ± 15.9^{b}	23.1 ± 16.2^{b}

WD = water depth; WT = water temperature; EC = conductivity; DO = dissolved oxygen; TSS = totalsuspended solids. Superscript letters indicate the significant spatial differences of environmental factors (p< 0.05);the same letters indicate nonsignificantdifferences.

East Taihu Lake exhibits a mild eutrophication. Nutrients are higher in OWA and in summer.

2-MIB dynamics

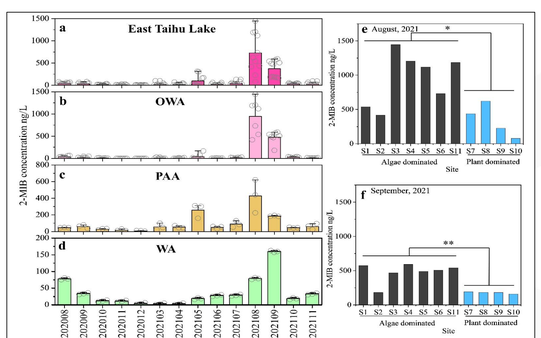

Fig. 3. Seasonal dynamics of the 2-MIB concentration at the different functional areas. Specifically, (e) and (f) show the 2-MIB concentrations at all sampling sites and analyze the differences between plant- and algae-dominated areas.

2-MIB risk assessment

The 2-MIB concentration was lowest in winter and highest in summer (max 1446.0 ng/L, August 2021).

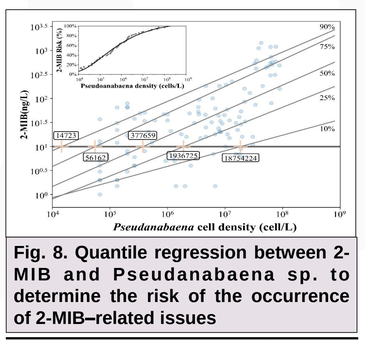

Fig. 8. Quantile regression between 2-MIB and Pseudanabaena sp. to determine the risk of the occurrence of 2-MIB–related issues

DENSITY	RISK
3.8 × 10^{5} cells/L	50%
1.8 × 10^{7} cells/L	90%

Phytoplankton community and 2-MIB producer(s)

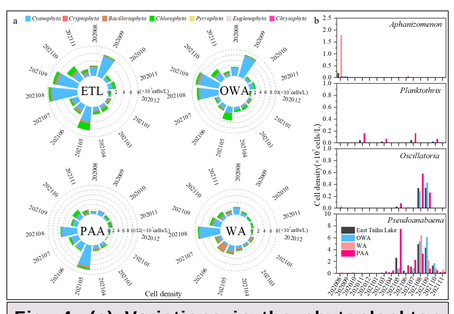

Fig. 4. (a) Variations in the phytoplankton community and (b) potential 2-MIB producers in different areas of East Taihu Lake. ETL = East Taihu Lake

Table 2. Identification of MIB producers according to the ranking protocol

Specie	R	p-value	FP%	FN%	Removed by
Pseudanabaena	0.71	0.001	4.8%	5.4%	-
	0.45	0.001	46.7%	0%	FP%
Planktothrix	0.078	0.27	-	-	R
Aphanizomenon	−0.019	0.53	-	-	R
Merismopedia	0.19	0.05	43.0%	3.6%	FP%
Chlorella	0.16	0.05	7.2%	17.3%	FN%

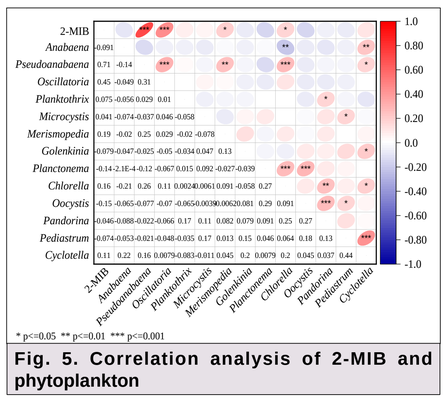

Fig. 5. Correlation analysis of 2-MIB and phytoplankton

The correlation analysis showed a general correlation between 2-MIB and Chl-a (R = 0.43, p < 0.01), and a very strong correlation with *Pseudanabaena* sp. (R = 0.71, p < 0.001). In addition, only *Pseudanabaena* sp. concurred with the FP% and FN% tests, being the top candidate in all scenarios.

PCA and potential driving factors

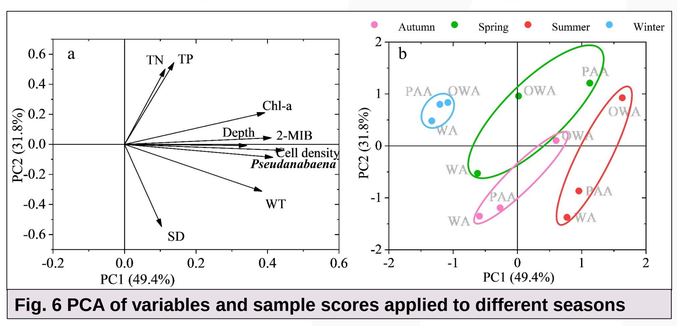

Fig. 6 PCA of variables and sample scores applied to different seasons

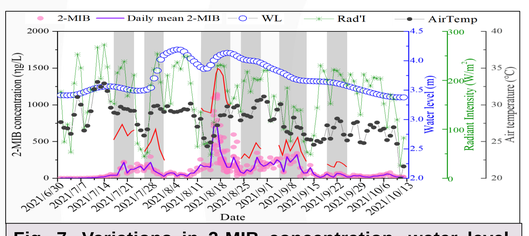

Fig. 7. Variations in 2-MIB concentration, water level, radiant intensity, and water temperature from July 2021 to October 2021 in East Taihu Lake; the red lines indicate similar trend between 2-MIB and radiant intensity.

This finding indicated that high temperature promoted the dominance of *Pseudanabaena* sp. and the release risk of 2-MIB. 2-MIB production was reduced in the dense macrophyte-dominated PAA and WA in the summer and early autumn of 2021, whereas it was higher in the OWA during these periods. Therefore, we concluded that Pseudanabaena growth was not sensitive to low N availability but favored high TP. Our results suggested that the 2-MIB trend was found to coincide with that of radiant intensity which afects underwater lights in 6 periods.

Conclusions

The present study revealed that the 2-MIB outbreak in East Taihu Lake was closely related to *Pseudanabaena sp*. In the macrophyte-abundant PAA and WA, 2-MIB concentration was significantly lower (p < 0.001) than in the phytoplankton-dominated OWA. This result indicated that the macrophyte-dominated state could mitigate the odor issues in shallow lakes. The causes of *Pseudanabaena* outbreak and high 2-MIB were associated with eutrophication (high TP), seasonal gradients (high WT), water clarity (high turbidity, low-light conditions), and hydrometeorological processes. Based on risk assessment, the risk of 2-MIB exceeding 10 ng/L in lake water is up to 90% if the cell density of *Pseudanabaena* is >1.8 × 10^{7}cells/L.

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