A preliminary study on the diatom distribution of the main lakes in the city of Guiyang, Guizhou Province

Yang Liu[1], Li Yang[2], Chendi Zhao[3], Yunchun Long[1], Jiaying Chen[4], Liang Chen[6], Jingjie Wu[1, *], Sunlin Hu[4,5,*]

[1]Guizhou Police College, Guiyang, Guizhou, China 550005
[2]Zunyi Medical University, Zunyi, Guizhou, China 563006
[3]Guizhou Weizheng Forensic Institute, Guizhou, China 550000
[4]Mindi Scientific (Shenzhen) Co., Ltd., Shenzhen, Guangdong, China 518071
[5]Minxue Scientific (Guangzhou) Co., Ltd., Guangzhou, Guangdong, China 511455
[6]Qinghai Provincial Public Security Department, Xining, Qinghai, China 810007

Abstract: Diatoms are a group of unicellular algae distributed throughout the world in a wide range of aquatic environments. Their unique biological and structural properties have propelled their applications in two critical fields: water environment monitoring and forensic science. In the presented paper, we surveyed the diatom distribution of the main lakes in the city of Guiyang, Guizhou Province, including diatom abundance, relative proportion of each genus, size distribution, which provided the necessary basis to improve water quality assessment frameworks and establish a foundational diatom dataset for forensic applications.

1 Introduction

Diatoms, unicellular algae encased in intricately patterned siliceous frustules, are among the most ecologically vital and taxonomically diverse microorganisms in aquatic ecosystems. As primary producers, they contribute ~20% of global oxygen production and form the base of aquatic food webs [1]. Beyond their ecological roles, diatoms serve as sensitive bioindicators due to their rapid responses to environmental changes, including nutrient fluctuations, pollution, and pH variations [2]. Their unique biological and structural properties have propelled their applications in two critical fields: water environment monitoring and forensic science.

In water quality assessment, diatoms are indispensable for evaluating ecosystem health. Diatom-based indices, such as the Trophic Diatom Index (TDI) and the Specific Pollution Sensitivity Index (IPS), are widely adopted under frameworks like the European Water Framework Directive (WFD) to diagnose eutrophication, acidification, and heavy metal contamination [3]. Recent advancements have expanded their utility to detect emerging contaminants, including microplastics and pharmaceuticals. For instance, Li et al. [4] demonstrated that diatom community shifts and frustule deformities correlate strongly with microplastic pollution levels, offering a novel biomonitoring tool. Similarly, DNA metabarcoding techniques now enable high-resolution taxonomic identification, enhancing the precision of diatom-based assessments [5].

In forensic science, diatoms have emerged as valuable forensic indicators, particularly in cases of drowning [6]. The principle underlying their use in drowning investigations is based on the fact that during drowning, water is inhaled into the lungs, and diatoms present in the water can enter the bloodstream through the alveolar - capillary membrane. These diatoms are then transported to various organs such as the liver, kidneys, and brain. The presence of diatoms in these organs, especially when they match the diatom species composition of the suspected drowning water source, strongly suggests a drowning death [7]. For instance, recent studies have shown that by analyzing the diatom assemblages in the organs of drowning victims and the surrounding water bodies, forensic scientists can accurately determine the location of drowning, even in complex scenarios where multiple water sources are involved [8]. This application has been further enhanced in recent years with the development of advanced microscopic and molecular techniques for diatom identification and analysis [9].

Guiyang, a karst-dominated city in southwestern China, hosts complex hydrological networks that are vital for regional ecosystems and urban water security. However, rapid urbanization and anthropogenic pressures threaten these water bodies, necessitating robust monitoring systems. Despite global advancements in diatom research, studies focusing on Guiyang's unique aquatic environments remain sparse. This knowledge gap impedes both ecological management and forensic applications (e.g., drowning site identification) in the region. By systematically investigating diatom distribution patterns in Guiyang's major water bodies, this study aims to enhance water quality assessment frameworks tailored to karst

* Corresponding author: Jingjie Wu, wjj972@163.com, Sunlin Hu, sunlin.hu@aliyun.com

ecosystems and establish a foundational diatom dataset for forensic applications.

2 Materials and methods

2.1 Sampling sites and dates

Water samples were collected from major water bodies in the city of Guiyang, Guizhou Province, including: Hongfeng Lake, HuaXi Lake, BaiHua Lake, Aha Lake, and QianLin Lake (see Figure 1). Six water samples were collected from each water body, as detailed in Table 1.

Table 1. Sampling sites and dates

Lakes	Sampling sites	Sampling dates
HongFeng	Figure 2 #1: the area under Huayudong Bridge #2-6: the area around Youercun Village	2024/10/26
HuaXi	Figure 3 #1-2: Pingqiao Section #3: HuaXi Park Section #4-6: Shili Riverbank Section	2024/10/27
BaiHua	Figure 4 #1-3: BaiHua Lake Scenic Area #4-6: the area around Ganchangba	2024/10/27
Aha	Figure 6 #1: Jinzhong River Section #2-6: the area around Aha Village	2024/10/27
QianLin	Figure 5	2024/10/29

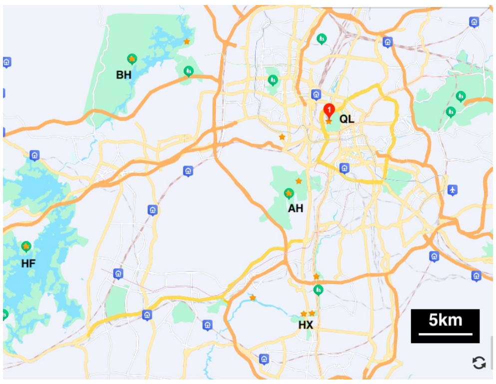


Figure 1. Caption of the Figure 1. Below the figure.

HF: HongFeng Lake; HX: HuaXi Lake; BH: BaiHua Lake; AH: Aha Lake; QL: QianLin Lake

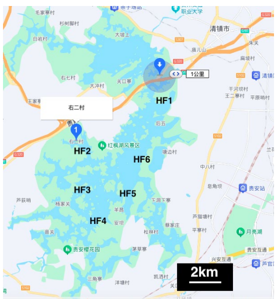


Figure 2. Sampling sites of HongFeng Lake

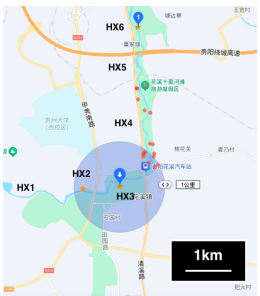


Figure 3. Sampling sites of HuaXi Lake

Figure 4. Sampling sites of BaiHua Lake

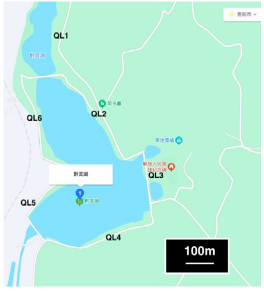


Figure 5. Sampling sites of QianLin Lake

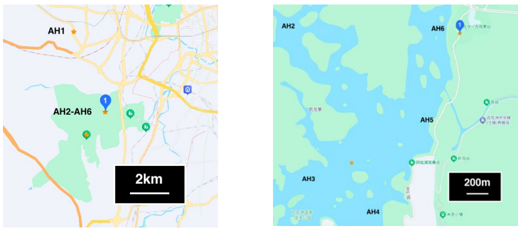


Figure 6. Sampling sites of Aha Lake

2.2 Procedures of sampling and sample preservation

Surface water samples (1000 mL) were collected from each site using clean plastic bottles. Formaldehyde solution (for fixation) was added to each sample to achieve a final concentration of 4% (v/v).

2.3 Water Sample Processing

A 10 mL aliquot of each water sample was placed in a plastic test tube, mixed with 8 mL of analytical-grade concentrated nitric acid, and digested at 80°C for 30 minutes using a graphite digestion instrument. The samples were then filtered and coated [10].

2.4 Diatom Analysis by scanning electron Microscopy (SEM)

Scanning electron microscopy (SEM), with much higher magnification and larger depth of field compared to light microscopy (LM), proves ideal for accurate diatom detection and classification (see Figure 7).

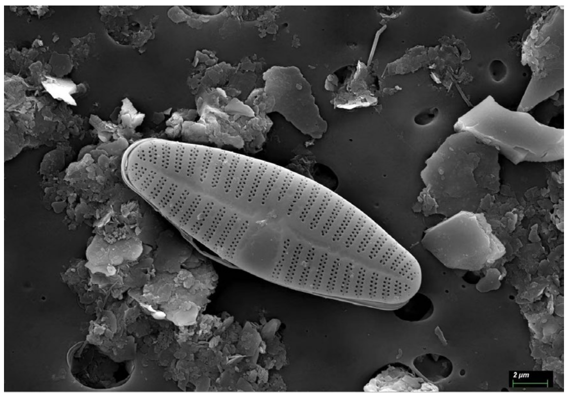


Figure 7. SEM image of Achnanthes

Therefore, qualitative and quantitative analysis, as well as size measurement of diatoms on the coated membranes was performed using SEM [10].

3 Results and Discussion

3.1 Diatom Abundance

As shown in Figure 8, diatom concentrations of all lakes except HuaXi Lake exceeded 500 valves/mL. For QianLin Lake, the diatom concentrations were similar across the sampling sites (spaced ~500 m apart). In contrast, the lakes with sampling sites spaced farther apart (>2 km), such as BaiHua Lake, exhibited significant variations in diatom abundance.

More detailed information on the diatom concentrations of these lakes is as follows:

HongFeng Lake: Diatom concentrations ranged from 693 to 2,539 valves/mL, exhibiting a progressive decline from Sampling Site #1 to #6 (Figure 8a).

Aha Lake: Diatom concentrations spanned 363 to 3,428 valves/mL, with the highest value nearly 10 times the lowest. A decreasing trend was observed from Site #1 to #6 (Figure 8b).

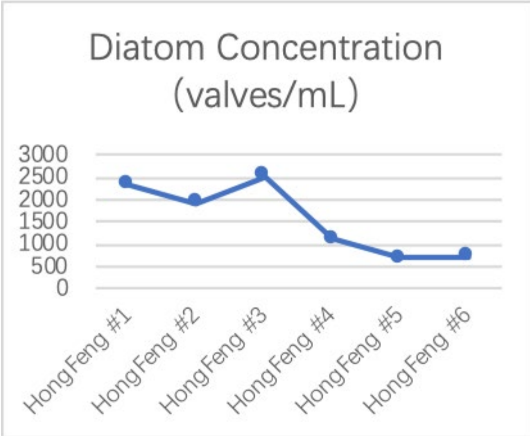
BaiHua Lake: Diatom concentrations fluctuated between 325 and 2,439 valves/mL across Sites #1 to #6 (Figure 8c).

HuaXi Lake: Diatom concentrations were consistently low (186–466 valves/mL), with relatively higher values at Sites #1 and #6 (Figure 8d).

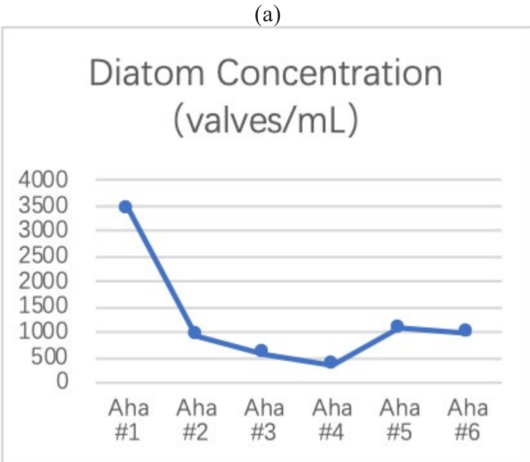
QianLin Lake: Diatom concentrations were similar across all sites, ranging from 849 to 1,081 valves/mL. (Figure 8e).

Diatom concentrations are strongly correlated with water quality parameters, serving as reliable bioindicators of ecological conditions. Elevated diatom abundance often correlates with nutrient enrichment (e.g., nitrogen and phosphorus), as eutrophic conditions promote the proliferation of opportunistic species like Cyclotella and Fragilaria [3] onversely, oligotrophic systems typically host lower diatom densities but higher diversity, dominated by sensitive taxa such as Achnanthes [11]).

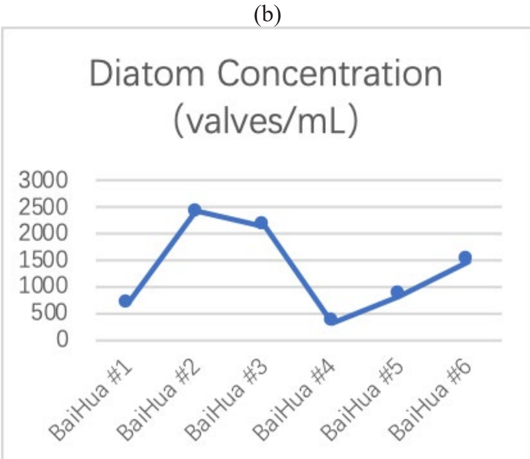
According to [] (Rimet et al., 2019) [11], diatom concentration thresholds for water quality classification are as follows: clean water bodies (50–1,000 cells/mL), moderately polluted water bodies (1,000–10,000 cells/mL), and heavily polluted water bodies (>10,000 cells/mL). Based on these criteria, HuaXi Lake and QianLin Lake fall within the clean water category, while the other lakes (HongFeng Lake, Aha Lake, and BaiHua Lake) are classified as moderately polluted.



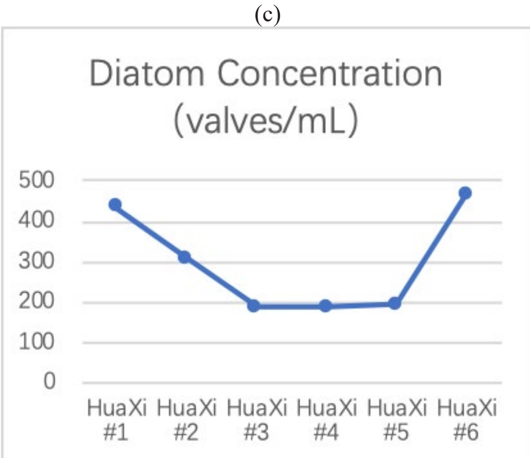
(a)



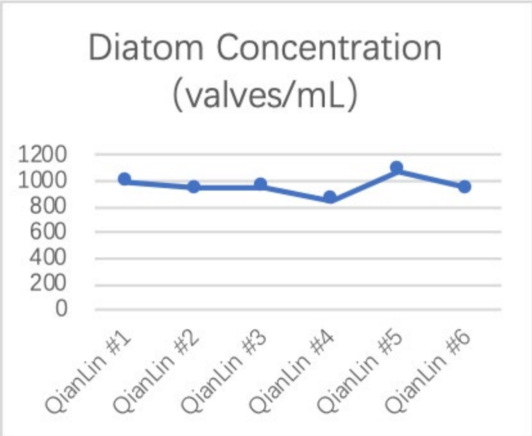
(b)



(c)



(d)



(e)

Figure 8. Concentrations of diatoms in water samples

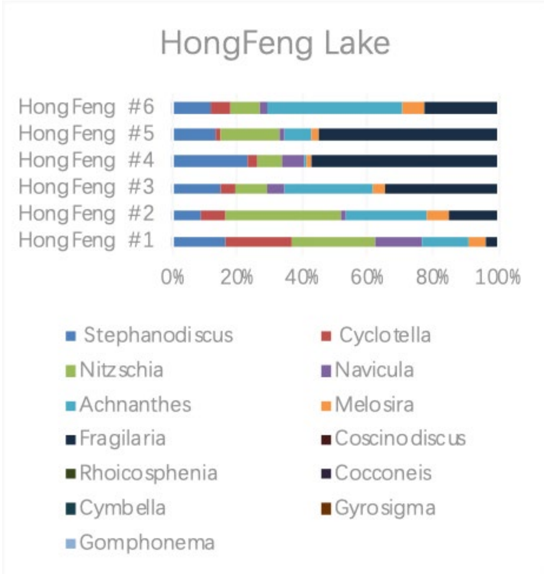
3.2 Taxonomic composition

The diatom genera composition, relative proportions of each genus, and the dominant genera with their relationships to water quality are illustrated in Figure 9 and Tables 2 and 3.

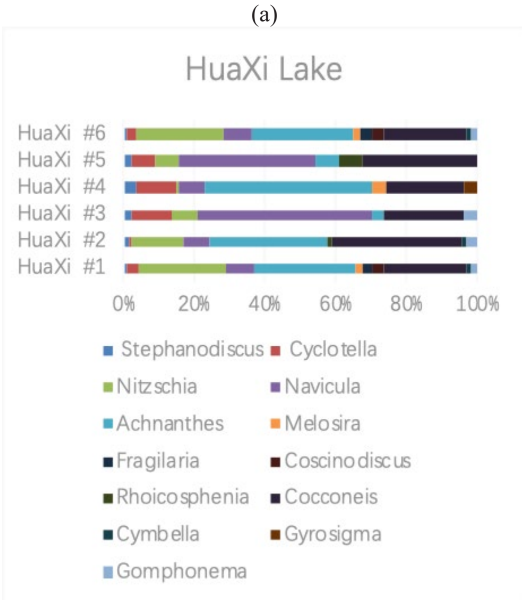
Based on diatom concentrations, taxonomic composition, and dominant genera, a preliminary assessment of water quality can be made. For example, as shown in Fig. 8 and 9, and Tables 2 and 3, Sample #1 from Aha Lake exhibited a diatom concentration of 3,428 valves/mL, dominated by Stephanodiscus (indicative of moderately polluted water), while Sample #2 from Aha Lake had a lower concentration (937 valves/mL) with Achnanthes as the dominant genus (a bioindicator of clean water). This contrast suggests that the water quality at Site #2 is superior to that at Site #1.

However, to accurately assess the water quality of Guiyang's major water bodies, it is essential to integrate established evaluation frameworks from other regions (e.g., the European Water Framework Directive) [12] with comprehensive local studies on diatom-water quality relationships. This study represents an initial step; further research is needed to develop a reliable diatom-based water quality assessment system tailored to Guiyang's unique hydrological and ecological conditions.

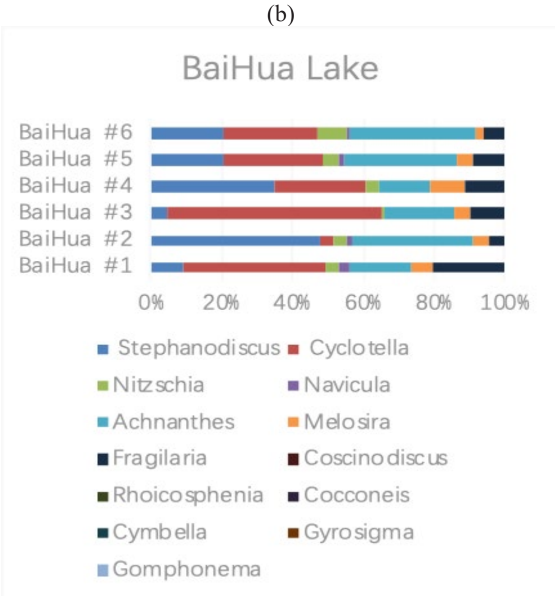
On the other hand, as shown in Figure 9, taxonomic composition varied across the lakes, and even within the same lake, sampling sites also differed in genera or relative abundance of each genus. Consistency in genera proportions between the drowning fluid and the organs of the drowned cadaver, if present, might be able to aid in determining the drowning site in forensic casework.



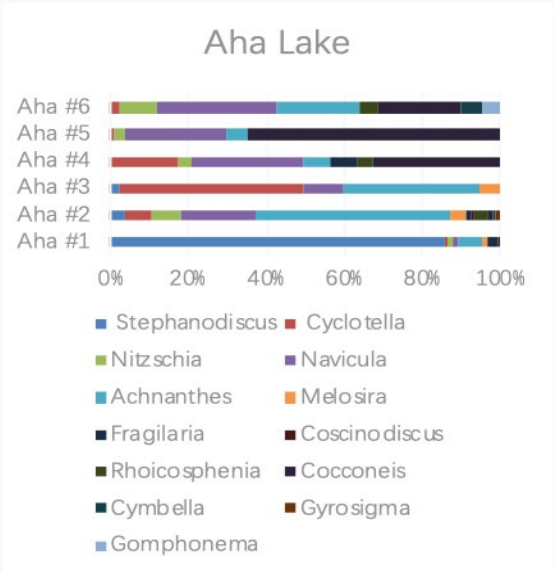
(a)



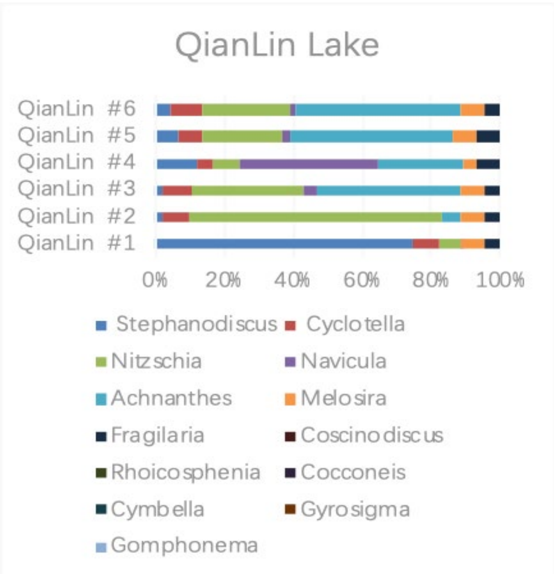
(b)



(c)



(d)



(e)

Figure 9. Proportions of each genus of diatoms in water samples

Table 2. Dominant genera* in lakes

Lakes	Dominant genera in sampling sites
HongFeng	#1: Cyclotella, Nitzschia #2: Nitzschia, Achnanthes #3: Achnanthes, Fragilarua #4: Stephanodiscus, Fragilarua #5: Fragilarua #6: Achnanthes, Fragilarua
HuaXi	#1: Nitzschia, Achnanthes, Cocconeis #2: Achnanthes, Cocconeis #3: Navicula, Cocconeis #4: Achnanthes, Cocconeis #5: Navicula, Cocconeis #6: Nitzschia, Cymbella, Cocconeis
BaiHua	#1: Cyclotella, Fragilarua #2: Stephanodiscus, Achnanthes #3: Cyclotella, Achnanthes #4: Stephanodiscus, Cyclotella #5: Stephanodiscus, Cyclotella, Achnanthes #6: Stephanodiscus, Cyclotella, Achnanthes
Aha	#1: Stephanodiscus #2: Achnanthes #3: Cyclotella, Achnanthes #4: Navicula, Cocconeis #5: Navicula, Cocconeis #6: Navicula, Cocconeis
QianLin	#1: Stephanodiscus #2: Nitzschia #3: Nitzschia, Achnanthes #4: Navicula, Achnanthes #5: Nitzschia, Achnanthes #6: Nitzschia, Achnanthes

* Dominant genus was defined as the one with the relative proportion greater than 20%.

Table 3. Relationship between dominant genera and water quality

Genera	Implications for water quality
Achnanthes	The genus is a sensitive bioindicator of clean or oligotrophic water conditions. Species like Achnanthes minutissima thrive in low-nutrient environments and are highly susceptible to organic pollution and eutrophication, often disappearing in polluted waters [11]. Their presence correlates with good water quality, low turbidity, and minimal anthropogenic disturbance. Recent studies highlight their reduced abundance in systems contaminated by heavy metals or agricultural runoff, underscoring their utility in detecting early-stage ecological degradation [13] Monitoring Achnanthes populations thus aids in assessing nutrient levels and pollution impacts in freshwater ecosystems.
Cocconeis	This genus, characterized by oval-shaped valves, is a benthic diatom often associated with clean or moderately nutrient-enriched waters. Species like Cocconeis placentula thrive in well-oxygenated, low-turbidity environments, serving as indicators of good water quality [14]. However, some taxa tolerate organic pollution, colonizing substrates in eutrophic systems with high nitrogen levels [15]. Their sensitivity to heavy metals and habitat disruption (e.g., sedimentation) makes them valuable for assessing localized pollution impacts. Monitoring Cocconeis abundance and attachment patterns aids in evaluating nutrient dynamics and ecological stability in streams and lakes.
Cyclotella	This genus is a key indicator of nutrient dynamics in aquatic systems. Species like Cyclotella meneghiniana thrive in eutrophic waters, with increased abundance linked to elevated phosphorus and nitrogen levels [3]. They dominate in thermally stratified lakes during summer, reflecting nutrient enrichment from agricultural runoff or urban discharge. However, some Cyclotella taxa also adapt to oligotrophic conditions, suggesting intrageneric ecological variability [16]. Their sensitivity to silica depletion and temperature shifts makes them valuable for tracking eutrophication and climate-driven changes in water quality.
Fragilarua	The genus is a common bioindicator of nutrient-enriched or disturbed aquatic environments. Species like Fragilaria capucina thrive in eutrophic waters with elevated phosphorus levels, often dominating in lakes impacted by agricultural runoff [11]. They also tolerate organic pollution and sedimentation, reflecting degraded water conditions. However, their sensitivity to silica availability links their abundance to silica-to-phosphorus ratios, aiding in tracking nutrient imbalances [17]. Monitoring Fragilaria communities helps assess eutrophication trends and pollution impacts in freshwater ecosystems.
Navicula	This genus is a diverse diatom group serving as a

	bioindicator of moderate nutrient levels and organic pollution. Species like Navicula cryptocephala thrive in mesotrophic waters, reflecting balanced nutrient conditions, while others (e.g., Navicula gregaria) tolerate organic enrichment or heavy metals in polluted systems [15]. Their valve morphology and community shifts correlate with pH, dissolved oxygen, and nitrogen levels, aiding in diagnosing eutrophication or industrial contamination [18]. Monitoring Navicula dynamics helps assess ecological health and track pollution sources in rivers and lakes.
Nitzschia	The genus is a key bioindicator of water quality, often thriving in nutrient-rich or polluted environments. Species like Nitzschia palea are highly tolerant of organic pollution (e.g., sewage, agricultural runoff) and eutrophication, making their dominance a marker of degraded water conditions [11]. Conversely, their absence or low abundance typically reflects oligotrophic or clean systems. Recent studies also link Nitzschia to heavy metal and microplastic contamination, where they exhibit adaptive resilience but reduced biodiversity [4]. Monitoring Nitzschia dynamics thus provides critical insights into nutrient loads, pollution levels, and ecosystem health.
Stephanodiscus	This genus is a significant indicator of eutrophication in freshwater systems. Species like Stephanodiscus hantzschii proliferate in nutrient-rich waters, particularly under high phosphorus and nitrogen levels, often forming blooms in temperate lakes [19]. Their abundance correlates with seasonal nutrient influxes from agricultural or urban runoff. However, Stephanodiscus is also sensitive to silica limitation, which restricts frustule formation and growth, reflecting shifts in silica-to-phosphorus ratios [20]. Their dominance signals nutrient over-enrichment, aiding in diagnosing eutrophic conditions and guiding remediation strategies.

3.3 Size distribution

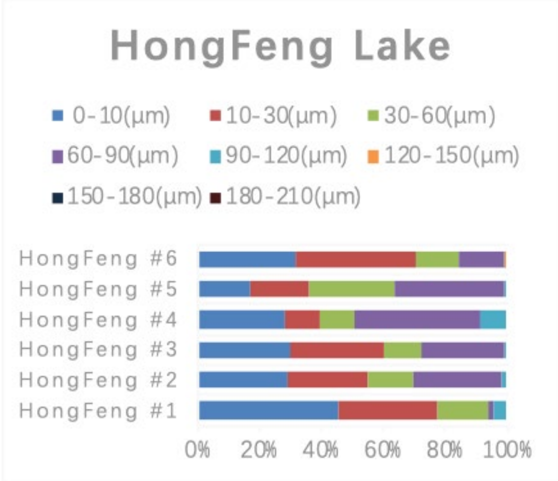
Most diatoms across all lakes were small (<30 μm), as shown in Figure 10. For instance, nearly 90% of diatoms in Aha Lake Sample #1 were <10 μm. In comparison, HongFeng Lake had more large diatoms (>30 μm), e.g., ~67% in Sample #5.

Diatom size analysis holds critical implications for ecology, environmental monitoring, and forensic science. Ecologically, size variations reflect life cycle stages, population dynamics, and resource allocation strategies.

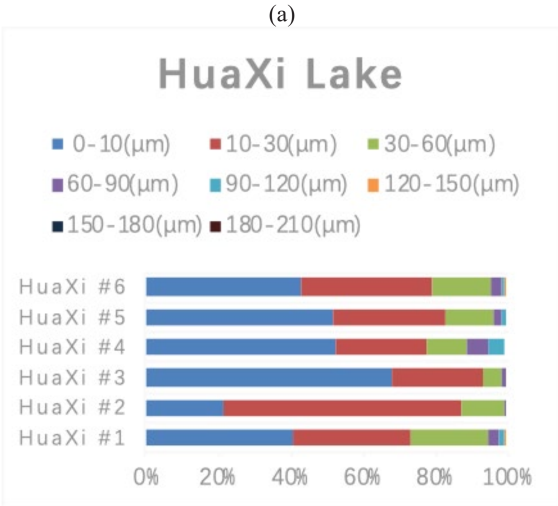
In environmental monitoring, diatom size serves as a sensitive biomarker for pollution. Heavy metals and microplastics can inhibit growth, reducing average size or causing deformities, whereas eutrophication promotes larger taxa like Melosira [13]. Forensic applications leverage size-specific diatom identification to enhance drowning diagnosis; smaller frustules (<10 μm) are more likely to penetrate human tissues, linking their presence to drowning sites [21].

Thus, size metrics provide multidimensional insights into ecological health, and forensic evidence. However, in the past, size analysis of diatom populations has not been widely studied because measurements are typically made using a light microscope, a time-consuming approach [22].

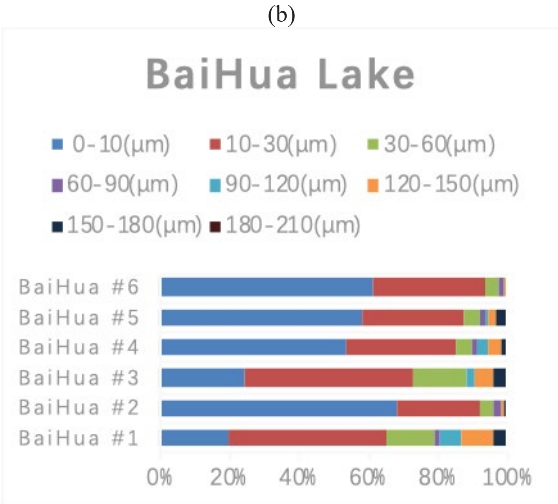
In the present study, we used an automated SEM to make the process of diatom size measurement more accurate and efficient. The development of a fully automatic system for diatom detection, classification and size measurement by our team based on automated SEM, deep learning, and diatom database, is still in progress.



(a)



(b)



(c)

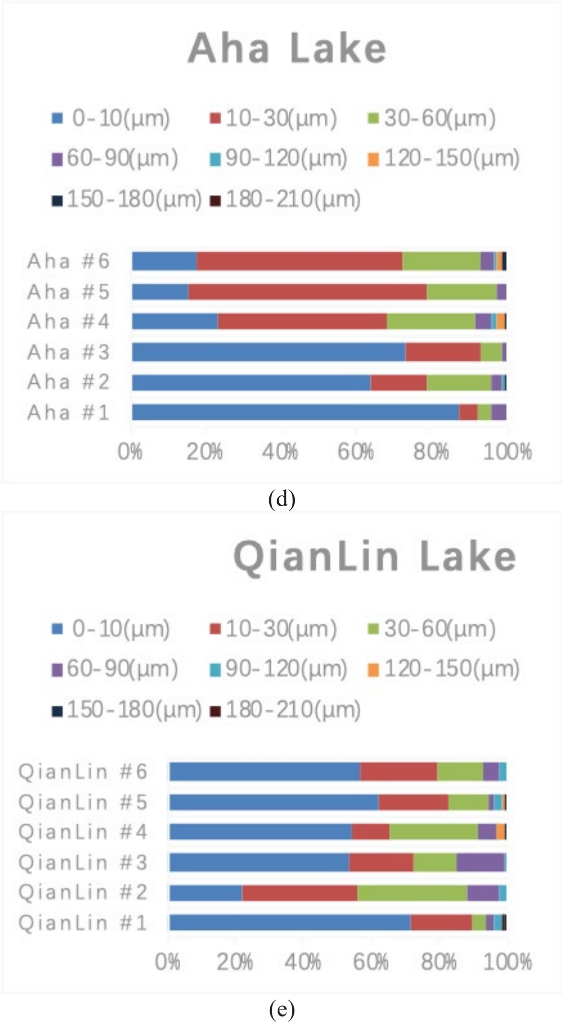


Figure 10. Size distribution of diatoms in water samples

4 Conclusions

A preliminary survey on the diatom distribution of Guiyang's water bodies yielded the following:

1. Diatom abundance varied significantly across lakes and even within individual lakes (>2 km between sampling sites).
2. Diatom genera composition differed between lakes. Within the same lake, the genera and their relative proportions varied.
3. Small diatoms (<30 μm) dominated for all studied lakes.
4. SEM outperformed light microscopy (LM) for accurate diatom detection, classification and size measurement, and is recommended for future use.
5. Further research is needed to advance diatom applications in water quality monitoring and forensic science.

Acknowledgments

This study was financially supported by Guizhou Provincial Ordinary University Youth Science and Technology Talent Growth Project (No. Qianjiaohe KY [2022] 339).

References

1. Armbrust, E. V. (2009). The life of diatoms in the world's oceans. Nature, 459(7244), 185-192.
2. Smol, J. P., & Stoermer, E. F. (2010). The diatoms: Applications for the environmental and earth sciences. Cambridge University Press.
3. Wu, N., Faber, C., & Qu, Y. (2020). Diatom-based bioassessment in China: Progress under the Water Framework Directive. Ecological Indicators, 118, 106701.
4. Li, H., Zhang, R., & Chen, J. (2023). Diatom community responses to microplastic pollution in freshwater ecosystems. Environmental Pollution, 316, 120682.
5. Piredda, R., et al. (2021). Diatom DNA metabarcoding for water quality assessment: A comparative analysis. Molecular Ecology Resources, 21(3), 789-805.
6. Pollanen, M. S., & Chiasson, D. A. (1996). The role of diatoms in the diagnosis of drowning: a critical review. Journal of Forensic Sciences, 41(3), 413-420.
7. Nécrot, N., & Giroud, C. (2019). Diatoms in drowning: a review. Forensic Science International, 299, 1-10.
8. Li, X., et al. (2021). Application of diatom analysis in forensic identification of drowning cases in different water environments. Forensic Science Review, 33(2), 135-148.
9. Wang, Y., et al. (2020). Advances in molecular techniques for diatom identification in forensic science. Forensic Science Research, 5(4), 267-274.
10. Liu, C., Hu, S., Wen, J., et al. (2019). Technical Specification for Diatom Examination in Forensic Science: Microwave Digestion-Vacuum Filtration-Microscopy Method (GA/T 1662-2019).
11. Rimet, F., et al. (2019). Diatom-based assessment of river ecological status: A review. Ecological Indicators, 99, 172-185.
12. European Parliament. (2000). Directive 2000/60/EC: Water Framework Directive.
13. Wang, Y., et al. (2023). Diatom-based pollution tracking in urban watersheds. Science of the Total Environment, 856, 159112.
14. Lavoie, I., et al. (2020). Diatom-based indices for monitoring water quality. Water Research, 168, 115160.
15. B-Béres, V., et al. (2022). Diatom functional traits in biomonitoring: A meta-analysis. Ecological Indicators, 135, 108567.
16. Saros, J. E., et al. (2021). Climate-driven shifts in diatom assemblages. Limnology and Oceanography, 66(4), 1234-1245.
17. Chen, L., et al. (2023). Microplastic interactions with freshwater diatoms. Environmental Science & Technology, 57(8), 3201-3210.

18. Stevenson, R. J., et al. (2019). Freshwater Algae of North America. Academic Press.
19. Yang, J., et al. (2021). Diatom biodiversity patterns in subtropical rivers. Hydrobiologia, 848, 4567-4581.
20. Gibson, C. E., et al. (2022). Diatom community dynamics in temperate lakes. Freshwater Biology, 67(3), 512-525.
21. Zhao, X., et al. (2022). Forensic implications of diatom size in drowning cases. Journal of Forensic Sciences, 67(5), 1892-1901.
22. Spaulding, S. A., Jewson, D. H., Bixby, R. J., et al. (2012). Automated measurement of diatom size. Limnology and Oceanography Methods, 10(11), 882-890. DOI:10.4319/lom.2012.10.882.