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Research on the Characteristics of Benthic Diatom in the Longjiang River in Guangxi and Its Relationships with Heavy Metals Ions Pollution

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This paper performs sampling and analysis of benthic diatom communities in the Longjiang River in Guangxi province in both May and July. The positive correlation between dominant diatom communities and the contents of heavy metals in the water were obtained by analyzing water quality monitoring data. The major influencing factors of the heavy metal ion to the benthic diatom in the Longjiang River are the contents of Cd and Zn ions. Temperature does not have great influences on the dominant benthic diatom communities. According to the classification of ecological diatom communities, the diatom communities at various sampling points of the Longjiang River are the indicator species of polluted water. The significant correlations between the investigated diatom communities and water quality indicates that benthic diatom is very sensitive to heavy metals in water.

1. Introduction

In the river ecosystems, benthic diatom is widely distributed and can be found in various water bodies (Krizmanić et al., 2015). Diatom is extremely sensitive to changes in water environment. Environmental changes would lead to continuous changes in the species - those adapted to the environmental changes would multiply rapidly while those failing to adapt would die (Mangadze et al., 2016; Meng, 2017; Wang et al., 2017). Heavy metal can affect the growth of diatom, which would lead to malformation of diatom or even affect its genetic composition. Cadmium, lead, copper, mercury, etc. can heavily accumulate in diatom cells and interfere with cell metabolism, and eventually affect the growth and reproduction of diatom (Ding et al., 2012). Benthic diatom is useful indicator species for heavy metals. Different species of diatom have different tolerances to heavy metals, and their abundances can reflect the degree of pollution (Besse-Lototskaya et al., 2006). Nakanishi found the concentrations of Cu, Zn, Pb and Cd are significantly correlated with the abundance of Achnanthes minutissima (Nakanishi et al., 2004). Duong found that the abundances of Nitzschia palea, Encyonema minutum and Surirella angusta are positively correlated with the concentration of cadmium while the abundances of Nitzschia dissipata, Melosira varians and Navicula lanceolata are negatively correlated with the concentration of cadmium, Which can be utilizes to indicate the different tolerances and and thus can be an indicator for evaluating the effects of heavy metals (Duong et al., 2010). The experiments performed by De and Cunningham respectively also demonstrated that benthic diatom communities are good indicators of the heavy metal pollution in rivers (De et al., 2008; Cunningham et al., 2005).
Longjiang, the largest tributary of the Liujiang River, was once the primary source of domestic and agricultural water in Hechi, Guangxi. Since the 1960s, many industrial and mining enterprises have been established in the Longjiang River basin. Most of the production wastewater and domestic sewage produced there are discharged directly into the river without being treated. As a result, the water in the Longjiang River is greatly polluted. However, few studies focus on how diatom communities in Longjiang River have been influenced. In this study, we collected benthic diatom samples in Longjiang River in the May and September of 2013 to

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investigate benthic diatom compositions in Longjiang River. In addition, this study allowed us to determine the spatial and temporal changes in diatom communities. Finally, relationship of diatom communities with environmental factors, especially heavy metals, were explored. All these could help us to understand the response mechanism of benthic diatom to environmental stress in Longjiang River. The findings in this study could hopefully provide basic data and theoretical support for establishing a Longjiang biological monitoring and assessing system using benthic diatom.

2. Materials and methods

2.1 Study area and Sampling sites

Longjiang River is mainly located in the northwest of Guangxi (107°00'-109°20' E; 24°00'-26°00'N). It originates from the southwestern side of Moon Hill in Sandu, Guizhou, and flows southeast and merge into Liujiang River at Nandan, Liucheng County. The total length of Longjiang River is approximately 390 km. The whole Longjiang Basin is in the transitional zone of Yunnan-Guizhou Plateau to Guangxi Basin with the catchment area of 16,900 km^2. According to the geographic location of the Longjiang River, from the upper reaches of the Longjiang River to Longjiang Sancha Hydrological Station, there are a total of 9 sampling points, the distribution of which is shown in Figure 1.

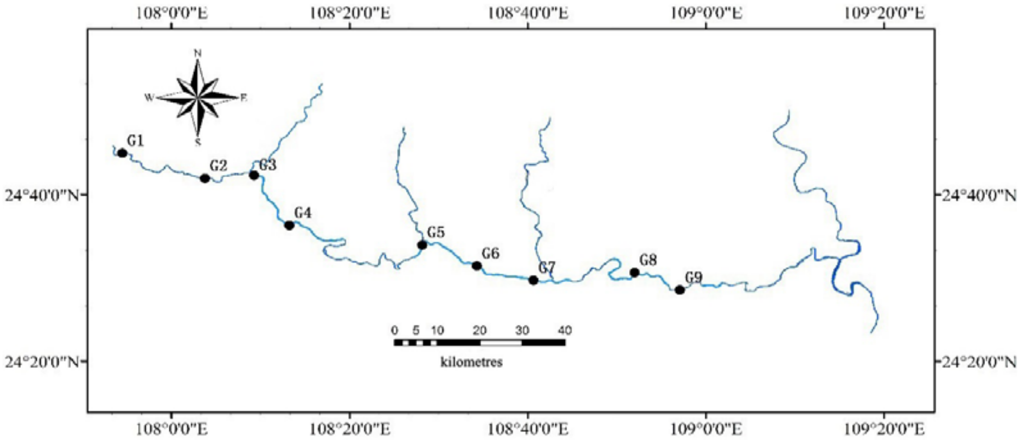

Figure 1: Distribution of sampling sites

2.2 Sampling and lab treatment

The samples were mainly collected according to the standards in EN 13946 (Institution, 2003) and EPA (Barbour et al., 1999), which are mostly epilithic diatom. By reference to the sampling method proposed by Liu (Liu et al., 2012), the research team chose rocks in open areas with certain flow rates and daylight, took diatom samples by brushing them away from the sunward side of the rocks with a clean toothbrush. At least five rocks were collected from each sampling site. Besides, the team used a PVC pipe with an inner diameter of 36 mm to fix the area, brushed benthic diatom away from rocks with a hard bristle toothbrush into the 500 mL sampling bottle, rinsed the toothbrush and the fixed areas of rocks and filled the cleansing solution to 500 mL. After thoroughly stirring the solution in the sampling bottle, the team took 50 mL and placed it into a specimen bottle and immediately added 2 mL of 10 % formalin solution to fix it. Then the team took it back to the laboratory for classification and identification of benthic diatom.

Water samples were collected, stored and measured according to the Water and Wastewater Monitoring and Analysis Methods (Fourth Edition) (The State Environmental Protection Administration, 2002). On the field, the HANNA HI9828 multi-parameter water quality analyzer was used to obtain the hydrogen ion concentration index (pH), water temperature (T), dissolved oxygen (DO) and conductivity (Cond), and the concentrations of calcium (Ca) and magnesium (Mg) ions are determinte by the HANNA 96752 portable calcium/magnesium ion meter. The five-day biochemical oxygen demand (BOD_5), permanganate index (COD_{Mn}) and contents of ammonia nitrogen (NH_4-N) and heavy metals were analyse in lab.

Diatom was identified mainly by reference to the EU standard method EN 14407 (Institution, 2005). A preliminary examination was carried out with 40 × 10 times light glass of Olympus microscope (identified by the BX41 in May and by the BX51 in September); the diatom species were identified and counted under the 100×10 times oil-immersion Olympus microscope, with the microscope stage moved like an arabic numeral

"2" . All intact diatom shells and those with a damage proportion of no greater than 1/4 were included in the identification and counting. On each sample slide, there were no fewer than 400 diatom shells. The population of species is expressed in relative abundance. The identification and naming of diatom species are mainly based on the identification systems proposed by Entwicklung und Gene and Lange-Bertalot (Entwicklung und Gene, 2010; Lange-Bertalot and Krammer, 2004), Round (Round et al., 1990), Winter (Winter and Duthie, 2000), Hu H.J (Hu and Wei, 2006) and Qi Y.Z (Qi, 1995; Qi and Li, 2004).

3. Results and analysis

3.1 Identification results of diatom in the Longjiang River

(1) Identification results of diatom sampled in May 2013
From the samples taken in May 2013, a total of 92 diatom species were identified (including subspecies, varietas and new synonyms), falling within two classes, six orders, eight families and thirty genera. Navicula, Achnanthes and Cymbella are dominant species. In terms of classification, the diatom in the Longjiang River mainly falls within two classes: Centricae and Pennatae, accounting for 8.97 % and 91.03 % of the total diatom classes.
At the sampling sites in Longjiang River in May 2013, diatom species with an occurrence frequency of over 70% include: Achnanthes and Cymbella, Fragilaria, Nitzschia, Cocconeis, Navicula, Cyclotella, Gomphonema, Luticola and Amphora.
(2) Identification results of diatom sampled in September 2013
From the samples taken in September 2013, a total of 142 diatom species were identified (including subspecies and varietas), falling within two classes, six orders, eight families and thirty genera. Navicula, Achnanthes and Cymbella are dominant species. In terms of classification, the diatom in the Longjiang River mainly falls within two classes: Centricae and Pennatae, accounting for 3.12 % and 96.88 % of the total diatom classes.
At the sampling sites in Longjiang River in September 2013, diatom types with an occurrence frequency of over 70 % include: Cymbella, Achnanthes, Navicula, Gomphonema, Encyonopsis and Fragilaria, etc.

3.2 Diatom species number, relative density and distribution of dominant species in Longjiang River

Through sampling of benthic diatom, it is found that diatom species at different sampling sites show significant differences. The dominant species at sampling sites vary greatly. The distribution and relative density of dominant species at the sampling sites are shown in Figure 2 and 3.

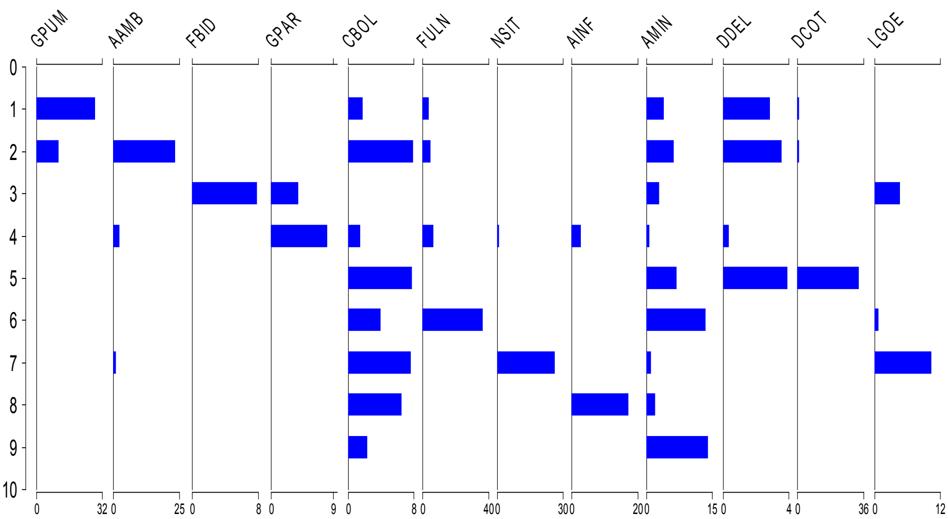

Figure 2: Distribution and relative density of dominant diatom species at the sampling sites in the Longjiang River (May 2013)

Notes: Gomphonema pumilum (GPUM); Aulacoseira ambigua(AAMB); Fragilaria bidens(FBID); Gomphonema parvulum(GPAR); Cyclotella bodanica var. lemanica(CBOL); Fragilaria ulna var.ul an(FULN); Nitzschia sinuata var.tabellaria(NSIT); Achnanthes inflata(AINF); Achnanthes minutissima(AMIN); Delicata delicatula(DDEL); Diadesmis contenta(DCOT); Luticola goeppertiana(LGOE).

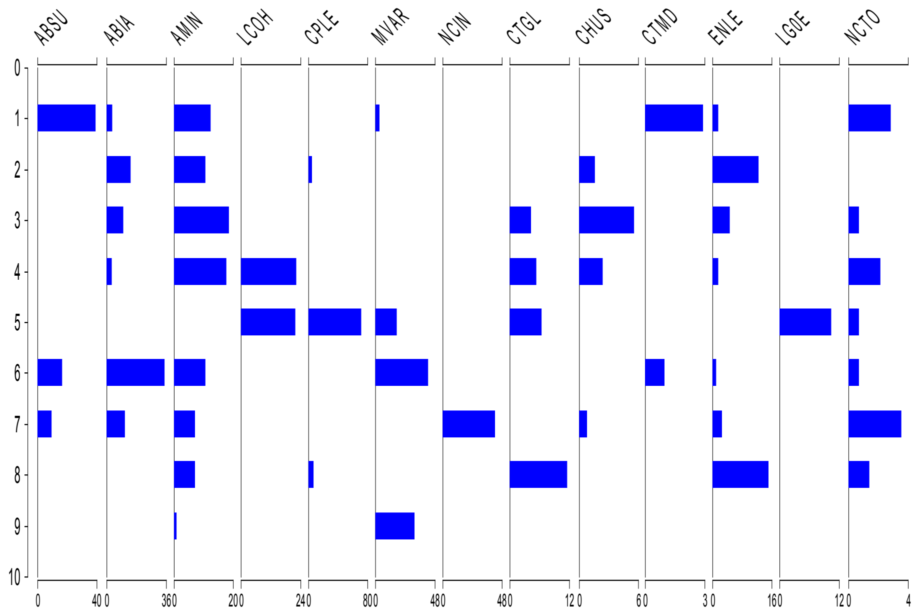

Figure 3: Distribution and relative density of dominant diatom species at the sampling sites (September 2013)

Notes:Achnanthes biasolettiana var.subatomus(ABSU); Achnanthes biasolettiana(ABIA); Achnanthes minutissima(AMIN); Luticola cohnii(LCOH); Cocconeis placetula var.euglypta(CPLE); Melosira varians(MVAR); Navicula cinta(NCIN); Cymbella turigidula(CTGL); Cymbella hustedtii(CHUS); Cymbella tumidula(CTMD); Encyonopsis leei(ENLE); Luticola goeppertiana(LGOE); Navicula cryptotenelloides(NCTO).

4. Discussion

Diatom, as a primary producer and an important part of the river ecosystem, participates in the operation and conversion of the whole river ecosystem and witnesses the changes in the ecosystem. It can respond rapidly to the changes in the river water quality and comprehensively reflect the joint ecological effects caused by various environmental factors (Vidakovic et al., 2014; Adler and Hübener, 2007). Pearson correlation coefficient is used to determine the close relations between the heavy metal ions in the Longjinag River and the dominant benthic diatom species. The "Ra" in the table indicates the relative abundance of diatoms, which is the percentage of the total number of diatoma. After calculation, the correlations between the relative abundance of dominant species and the heavy metal ions in the Longjiang River are shown in Table 1.

Table 1: Correlation between the relative abundance of diatom and heavy metals

		T	pH	Cd	Pb	Cu	Zn	Ra
	T	1						
	pH	-0.363	1					
	Cd	0.336	-0.789*	1				
2013.5	Pb	-0.415	-0.432	0.090	1			
	Cu	-0.021	-0.133	0.372	-0.136	1		
	Zn	0.448	-0.682*	0.748*	0.125	0.119	1	
	Ra	0.240	-0.449	0.831**	-0.189	0.555	0.719*	1
	T	1						
	pH	0.255	1					
	Cd	-0.450	-0.720*	1				
2013.9	Pb	0.519	0.281	-0.140	1			
	Cu	0.368	0.219	-0.035	-0.234	1		
	Zn	-0.088	-0.791*	0.822**	0.035	-0.229	1	
	Ra	-0.198	-0.415	0.765*	-0.096	0.084	0.777*	1

Note: ** stands for significant correlation at the significance level of 0.01 (bilaterally); and * stands for significant correlation at the significance level of 0.05.

As can be seen from Table 1, in May, there were correlations between the dominant species and the heavy metal ions in the Longjiang River. Cd was significantly correlated with the relative abundance of dominant diatom species at the significance level of 0.01, with a correlation coefficient of 0.831; Zn was significantly correlated with the relative abundance of dominant diatom species at the significance level of 0.05, with a correlation coefficient of 0.719, indicating that in May, the heavy metal ions in the water body had significant effects on benthic diatom. The content of heavy metal ions determines the distribution of dominant diatom communities, indicating that the main environmental factors affecting dominant benthic diatom communities in May were Cd and Zn; and heavy metals Pb, Cu and temperature T (°C) had little effect on diatom communities. There was a significant correlation between Cd and Zn at the significance level of 0.05, indicating that in May, Cd and Zn ions came from the same pollution source in the Longjiang River. pH was negatively correlated with these two heavy metals at the significance level of 0.05, indicating that the pH value of the water affects the contents of Cd and Zn. The higher the PH value is, the lower the content of Zn ions will be.

In September, there were also correlations between benthic diatom and heavy metal ions in the Longjiang River. The relative abundance of dominant diatom species was positively correlated with Cd at the significance level of 0.05, with a correlation coefficient of 0.765; and the relative abundance of dominant diatom species was positively correlated with Zn at the significance level of 0.05, with a correlation coefficient of 0.777, indicating that the distribution of dominant benthic diatom species is mainly affected by Cd and Zn ions. Compared with that in May, the correlation between Cd and Zn in the water was significant at the significance level of 0.01 in September, with a correlation coefficient of 0.822, indicating that Cd and Zn in the Longjiang River came from the same pollution source. pH was negatively correlated with both Cd and Zn at the significance level of 0.05, indicating that the pH value of the water affects the contents of Cd and Zn ions. The higher the pH value is, the lower the content of Zn ions will be.

5. Conclusions

Based on two on field samplings of benthic diatom in the Longjiang River and the identification at the laboratory, this paper finds out the relative dominant species at the sampling sites and performs relevant analysis. The following conclusions are obtained:

(1) By analyzing the correlations between benthic diatom communities and contents of heavy metal ions in the Longjiang River in May and September, this paper finds that the dominant diatom species are positively correlated with the contents of heavy metals in the water. The major influencing factors of heavy metal ions to the benthic diatom in the Longjiang River are the contents of Cd and Zn ions; temperature has little effect on the dominant benthic diatom communities; Cd and Zn ions are from the same pollution source; and pH is negatively correlated with Cd and Zn ions.

(2) According to the classification of ecological diatom communities proposed by Spitale (Spitale et al., 2012), the diatom communities at various sampling points of the Longjiang River are the indicator species of water pollution. The significant relationship between the dominant diatoms and the contents of Cd and Zn ions, indicating that the increasing of Cd and Zn ions in the river will lead to the growth of contamination resistant diatom communities and the gradual death of non-contamination-resistant communities and showing that diatom is very sensitive to heavy metals in water.

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