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Seasonal characteristics of chlorophyll-a and its relationship with environmental factors in Yunmeng Lake of China

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Abstract

Sampling was carried out according to the season, in order to analyze the seasonal characteristics of chlorophyll-a and its relationship with environmental factors in Yunmeng Lake on1st May, 12th August, 1st October and 14thDecember of 2013. The results showed that the average annual water temperature, pH, TP, TN and chlorophyll-a concentration in Yunmeng Lake was 15.9°C, 7.12, 0.07 mg l^{-1}, 1.58 mg l^{-1} and 30.60 µg l^{-1} respectively. The water quality was Class IV water or eutrophic type. Water chlorophyll-a was significantly positive with pH and TP(R^2=0.6077 $p<0.01$; R^2=0.5855 $p<0.01$), low correlation with water temperature (R^2=0.0566 $p>0.05$). lg ($Y_{Chl.\ a}$) was significantly positive with lg(X_{TP}) (R^2=0.5176 $p<0.01$), N/P was 22 and P may be restricted.

Key words

Andi reservoir, Chlorophyll-a, Lake yunmeng, Total nitrogen, Total phosphorus

Introduction

Reservoirs are semi-artificial and semi-natural waterbodies that fall between rivers and lakes (Han, 2010). Being the most important human project in terms of the influence to the water bodies, reservoirs play a crucial role in drinking water supply, flood control, power generation, irrigation, as well as ensuring the amount of water for ecological purposes and development of tourism in downstream areas (Li *et al*., 2013). They became sensitive and fragile due to human disturbances and thus, water eutrophication in reservoirs have become a significant problem as a subtype of water pollution (Gao *et al*., 2009). Chlorophyll is an important component of phytoplankton (Wang *et al*., 2014), and the concentration of Chlorophyll-a is an important index in examining phytoplankton (Kuang *et al*., 2005; Tian *et al*., 2015; Wu *et al*., 2011). The concentration of Chlorophyll-a reflects the biomass of phytoplankton and thus, acts as an important indicator for determining the trophic status of water body and studying water habitat (Lu *et al*., 2003).

Yunmeng Lake (Andi Reservoir) is the major source of drinking water in Linyi City. An accurate evaluation of its environmental condition has profound scientific and social significance (Xu *et al*.,2010; Ni *et al*., 2010; Liu, 2012). In the present study water samples from Yunmeng Lake were collected during different seasons to understand seasonal fluctuations of Chlorophyll-a and environmental factors and to reveal the underlying mechanism.

Materials and Methods

Studied region : Yunmeng Lake (also known as Andi Reservoir) was constructed in 1959 at the confluence of Dongwen River (tributary of Yi River) and Zi River, located at 35°27'–36°02'N, 117°45'–118°15'E. It is the second largest reservoir in Shandong Province, controlling a watershed of 1693 km^2 and has a volume of 749,000,000 m^3. It is a large reservoir mainly used for flood control and irrigation, with auxiliary purposes including power generation, city drinking water supply, aquaculture and tourism. It was designated as the major drinking water source of urban Linyi in 1996.

Methodologies : Seven sampling sites in the lake were selected and four samplings were carried out during four different seasons i.e., on 1st May, 12th August, 1st October and 14th December, 2013, respectively. At every sampling site, 50 cm sub-surface water was collected in two 250 ml volumetric flasks. Standard methods were followed for processing of water samples (State Environmental Protection Administration 2002; Surface Water Quality Standards 2002). During sample collection, temperature and pH were measured with Martini instruments (Ph–56). Chlorophyll-a concentration was measured by spectrophotometry, using ethanol as an extractant. Total nitrogen and Total phosphorus was measured by potassium persulfate-UV spectrophotometry and molybdenum, antimony anti spectrophotometry, implemented by Shikang Water Company and Linyi Municipal Water Corporation, Bancheng Water Plant.

Statistical analysis : Correlation between Chlorophyll-a and water environmental factors which included water temperature, pH, TN and TP, using regression functions were analyzed. All the analyses were implemented by SPSS 17.0 (Chinese version).

Results and Discussion

Seasonal fluctuations in water environmental factors of the lake : Water temperature ranged between 6.7 ºC–29.3 ºC with significant seasonal differences ($p<0.05$) (Fig. 1A), and round the year average temperature was 15.9 ºC. pH ranged between 6.96–7.21 without significant seasonal differences ($p>0.05$) (Fig. 1B), round the year average pH was found as 7.12. Average TP around the year 0.07 mg l^{-1}, falling into class IV, seasonal values ranged between 0.02 mg l^{-1}–0.16 mg l^{-1}, corresponding to class II-V. Seasonal differences were huge and spring value was significantly higher than the

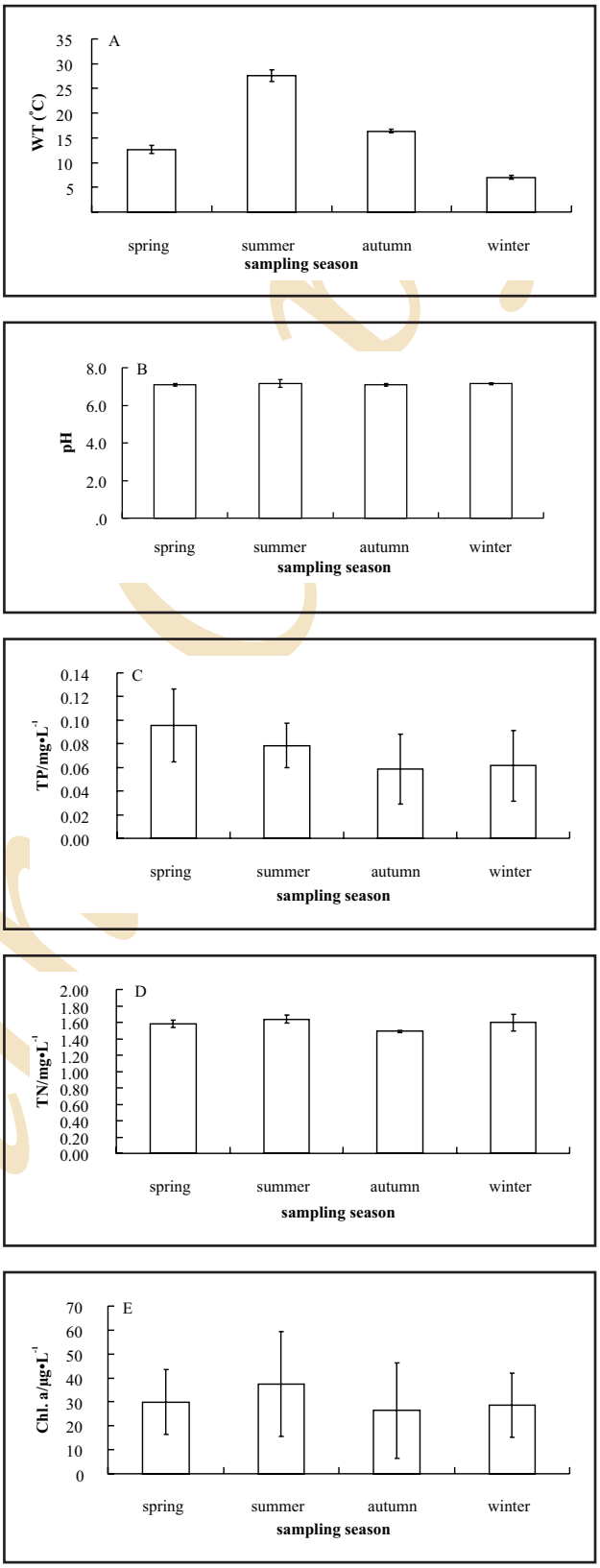

Fig. 1 : Seasonal changes of WT(A), pH(B), TP(C), TN(D) and Chlorophyll. a(E)

winter value (p<0.05) (Fig. 1C). Round the year average TN was 1.58 mg l^{-1}, which belonged to class IV, seasonal values were found between 1.26 mg l^{-1}–1.98 mg l^{-1}, which belonged to class IV-V; seasonal differences were significantly higher in summer than autumn (p<0.05) (Fig. 1D). On comparing the data of Yunmeng Lake with big lakes or reservoirs within 300 km distance, and it was found that in terms of TN, Dongping Lake (3.21 mg l^{-1}) (Sun *et al*., 2006) > Nansi Lake (2.86 mg l^{-1}) (Shi *et al*., 2011) > Yunmeng Lake (1.58 mg l^{-1}) > Shilianghe Reservoir (0.92 mg l^{-1}) (Han *et al*., 2012); when comparing TP, Dongping Lake (0.81 mg l^{-1}) (Sun *et al*., 2006) > Nansi Lake (0.12 mg l^{-1}) (Shi *et al*., 2011) > Shilianghe Reservoir (0.09 mg l^{-1}) (Han *et al*., 2012) > Yunmeng Lake (0.07 mg l^{-1}); in terms of Chlorophyll-a concentration, Yunmeng Lake (30.6 µg l^{-1}) > Dongping Lake (18.3 µg l^{-1}) (Sun *et al*., 2006) > Nansi Lake (8.75 µg l^{-1}) (Shi *et al*., 2011). These indicate that water quality of Yunmeng Lake is comparable to ordinary lakes and reservoirs. The desired goal for class-II water quality, is required for First Class Drinking Water Source Reserve.

Seasonal fluctuations of Chlorophyll a in Yunmeng Lake: The average Chlorophyll-a concentration was 30.60 µg l^{-1}, indicating that the water was eutrophic; the concentration fluctuated between 5.58 µg l^{-1}–72.54 µg l^{-1}, which fell in mesotrophic and eutrophic categories. No significant differences were noted during different seasons (p>0.05) (Fig. 1E), but significant differences existed between sampling sites (p<0.05).

Analysis of the correlations between Chlorophyll.a concentration and environmental factors : Many researches have shown that phytoplankton's growth is influenced by water temperature and pH (Wang *et al*., 2012; Mei *et al*., 2013; Wang *et al*., 2014; Tian *et al*., 2015). The findings of the present study suggest that the correlation between Chlorophyll-a and water temperature was insignificant (R^2=0.0566 p>0.05) (Fig. 2A), while a significant and positive correlation (R^2=0.6077 p<0.01) (Fig. 2B) existed between Chlorophyll-a and pH, which is comparable to the case Dishui Lake (Mei *et al*., 2013).

Several studies indicate that TN/TP ratio is more directly related to the growth of phytoplankton as compared to TN or TP only. When N/P is greater than 7, phosphorus might be a limiting nutrient; otherwise nitrogen might be a limiting nutrient (Lau and Lane, 2002; Chen *et al*., 2007; Liu *et al*., 2011; Wang *et al*., 2014; Thangaradjou *et al*., 2014).

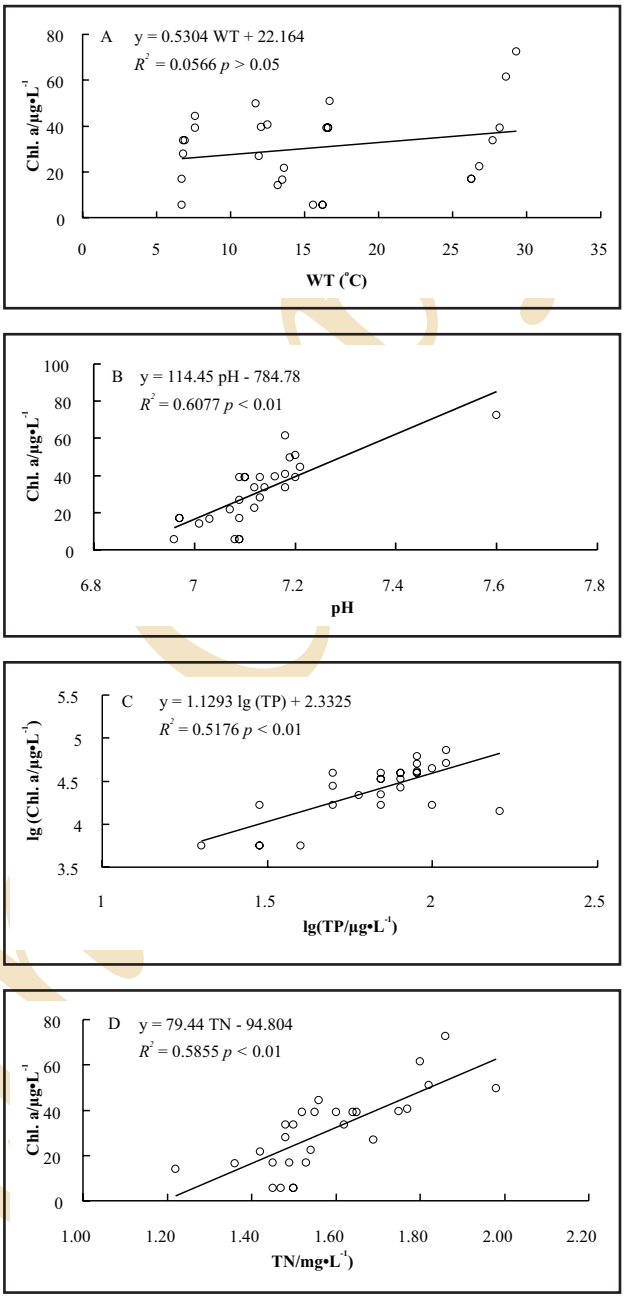

Fig. 2 : Correlations between Chlorophyll. a and WT(A), pH(B), TP(C), TN(D)

All round the year, the average water temperature, pH, TP, TN and Chlorophyll-a concentration was 15.9 ºC, 7.12, 0.07 mg l^{-1}, 1.58 mg l^{-1} and 30.60 µg l^{-1}, respectively. The water of Yimeng Lake belongs to class IV or meso-eutrophic type. A lot of effort is needed to achieve the goal of class-II water quality, as it is recommended for First Class Drinking Water Source Reserve. A significant and positive correlation was noted between Chlorophyll-a and TN (R^2=0.6077

$p<0.01$), as well as between Chlorophyll-a and pH ($R^2=0.5855$ $p<0.01$), while no significant correlations existed between Chlorophyll-a and water temperature ($R^2=0.0566$ $p>0.05$). $\lg(Y_{Chl.\ a})$ and $\lg(X_{TP})$ were significantly and positively correlated ($R^2=0.5176$ $p<0.01$). The N-P ratio was 22 that suggests phosphorus as a limiting nutrient.

Lake is a key to water conservation, where ecosystem plays a crucial role in self-purification of water, and these areas are especially sensitive to non-point source the watershed. Authorities should convert the farmland at the shore back to wetland, which will gradually increase the coverage of aquatic plants, such as reed and calamus. In order to restore the ecological functions of pristine wetland, fish that are helpful in water purification, like Silver carp (*Hypophthalmichthys molitrix*) and Bighead carp (*Hypophthalmichthys nobilis*) should be released to control the growth of algae and enhance the self-purification capacity. Farmlands at high-altitude areas near lakeside should be converted into forest. Thus, the non-point source pollution near Lake Yunmeng could be efficiently reduced, and the lakeside areas will have much stronger capacity to hold up and purify N-P pollutants.

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