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Accelerated Nitrogen Burial in a Shallow and Eutrophic Lake (the Chaohu Lake) in Southeastern China

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Abstract

Lakes are important nutrient sink with substantially nitrogen stocking in sediment. Two sediment cores were collected and analyzed to study the temporal changes of nitrogen sedimentation in a shallow, dam-controlled Chaohu Lake in Southeastern China. The results showed that the nitrogen sedimentation rates varied significantly between the periods of 1860s to 1970s and 1970s to 2016. The average rates were 1.165 Gg N yr^{-1} before 1970s and 2.455 Gg N yr^{-1} after 1970s for the entire lake. And the annual nitrogen sedimentation amount was 1.165 Gg N before 1970s and 2.455 Gg N after 1970s for the Chaohu Lake, indicating an accelerated trend in nitrogen burial. Our results may help to understand nitrogen cycling under dam-controlled lake ecosystems.

Introduction

Lakes are recognized to play an important role in global nitrogen (N) cycles and are marked by active filters for N retention [1-5]. Lakes are also considered to be a sink that bury considerable organic matter in the sediment [6,7]. Organic matter in the sediment mainly originates from in-lake primary production and terrestrial organic matter input. After depositing, 30% of nitrogen was removed in the first 5-year and 5% decreased in the following 22-year [8]. Even though nitrogen burial in the sediment is regarded as part of terrestrial nitrogen cycle [9,10], the changes in lake nitrogen sedimentation have been paid less attention, particularly for lakes during the eutrophic processes changing from oligotrophication to eutrophication.

The Chaohu Lake, a typical shallow and dam-controlled lake, is located in the Anhui Province, Southeastern China. The lake has received unprecedented pollutants in past few decades and experienced serious water quality deterioration since 1980s. Here, we reported data from two sediment cores that reflect the nitrogen sedimentation rates change since 1860s. This study tests the hypothesis that nitrogen burial rates were significantly promoted during the lake eutrophication processes since 1970s.

Sampling and Analytical Methods

Two sediment cores with 28-cm and 29-cm in length, which located at the east lake (ECH, 117°36′14.38″E,31°31′28.92″N) and west lake (WCH, 117°22′20.49″E,31°37′50.59″N), respectively, were collected in October 2016.Core samples were slit with 1-cm interval *in situ* and weighed wet, freeze-dried and then reweighed after transporting to laboratory. Dried samples were stored in sealed containers for over 20 days to get radioactive equilibration and then were tested for radionuclide (^{210}Pb, ^{226}Ra and ^{137}Cs) by gamma spectrometers equipped with high pure germanium detection (GWL-120-10, ORTEC, USA). Total nitrogen (TN) was determined by element analyzer (Vario MICRO cube, Elementa, Germany). Sedimentation rates were calculated by applying composite ^{210}Pb dating model [11] using the peak of ^{137}Cs at 1963 as a time marker to validate the sediment chronology. All the figures and statistical analysis were performed in MATLAB software (R2016b, Math Works, Natick, USA).

Results and Discussion

The chronology calculated by ^{210}Pb model dates revealed that sediment cores dated to 1860s and 1870s with ^{137}Cs peak at 17-cm and 16-cm for the WCH and the ECH, respectively (Figure 1). The dry mass accumulation rates (DMAR) showed a steadily increase before 1960, and followed by a period of stability within the range of 0.152 to 0.225 g cm^{-2} yr^{-1}. TN contents showed significant changes throughout the sediment core and increased steadily toward the top (Figure 2). The

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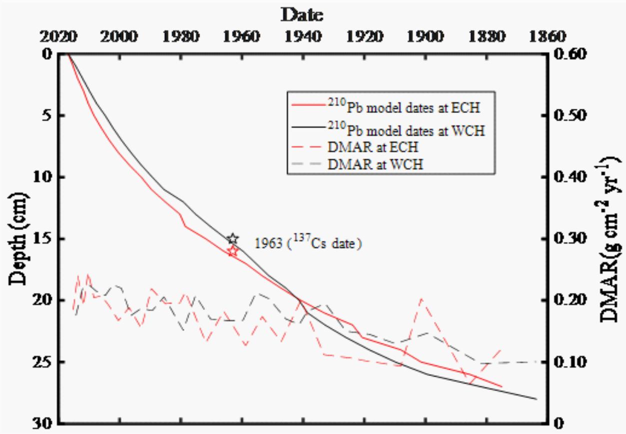

Figure 1: Dates and sediment dry mass accumulation rates (DMAR) in the Chaohu Lake core using composite ^{210}Pb model and showing the depth of 1963 determined from ^{137}Cs date.

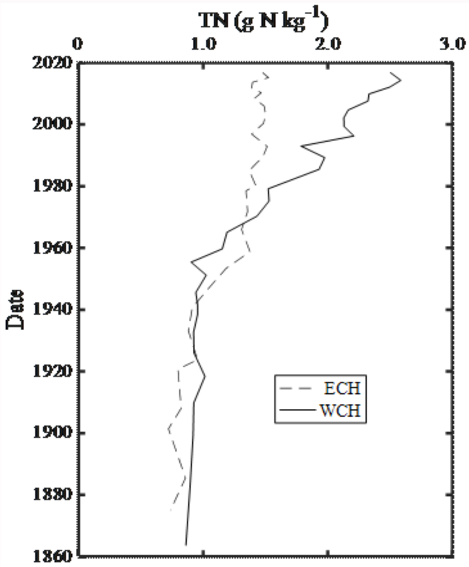

Figure 2: The vertical distribution of TN in the Chaohu Lake.

contents of TN ranged from 0.721 to 1.525 mg N g^{-1} (average: 1.236 mg N g^{-1}) and from 0.861 to 2.585 mg N g^{-1} (average: 1.539 mg N g^{-1}) for ECH and WCH, respectively. N sedimentation rates ranged from 0.468 to 3.666 g N m^{-2} yr^{-1} (average: 2.175 g N m^{-2} yr^{-1}) and from 0.897 to 5.665 g N m^{-2} yr^{-1} (average: 2.946 g N m^{-2} yr^{-1}) for ECH and WCH, respectively (Figure 3). We used one way ANOVA to analysis the changes in N sedimentation rates, and found that the rates after 1970s were significantly higher than that before 1970s for both the east and west lake regions. Before 1970s, the sedimentation rates ranged from 0.468 to 2.476 g N m^{-2} yr^{-1}(average: 1.424 g N m^{-2} yr^{-1}) for ECH and from 0.897 to 2.450 g N m^{-2} yr^{-1} (average: 1.679 g N m^{-2} yr^{-1}) for WCH, respectively. During this period, N sedimentation rates were increased by 0.0170 g N m^{-2} yr^{-1} for ECH and 0.0176 g N m^{-2} yr^{-1} for WCH, respectively. After 1970s, the rates ranged from 1.769 to 3.666 g N m^{-2} yr^{-1} (average: 2.776 g N m^{-2} yr^{-1}) and from 2.598 to 5.665 g N m^{-2} yr^{-1} (average: 4.212 g N m^{-2} yr^{-1}) for ECH and WCH, respectively. The rates in the east lake region were increased by 0.0225 g N m^{-2} yr^{-1}and were a little higher than that before 1970s, but the rates were sharply increased by 0.0656 g N m^{-2} yr^{-1} in the west lake.

We calculated annual N sedimentation amount by using the

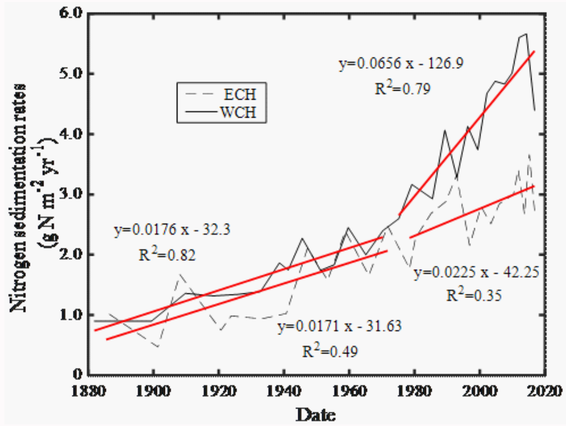

Figure 3: Variations of TN sedimentation rates in the Chaohu Lake, showing the change trend before 1970s and after 1970s for the eastern lake and western lake.

average sedimentation rates of the ECH and WCH and the surface area (587 km^2 and 196 km^2 for ECH and WCH, respectively), our result showed that the annual N sedimentation amount was 1.165 Gg N before 1970s and 2.455 Gg N after 1970s for the Chaohu Lake.

The increases of DMAR and TN sedimentation rates after 1960s resulted from intensive anthropogenic activities within watershed [12]. In particular, the high TN sedimentation rates of the Chaohu Lake after 1970s could be attributed to the high nutrient loading from the watershed input and high primary production in the lake. With the rapid development of socio-economy, increasing anthropogenic loading of N lead to undesirable eutrophication [13] and substantial increase of aquatic primary production [14]. Our unpublished data showed that the isotope values for δ^{15}N in lake sediments (ranged from +5.3‰ to +9.7‰) were close to these in the lake planktons (ranged from +9.5‰ to +12.5‰), but much higher than those in soils (ranged from 0 to 4‰), indicating TN in sediments could originate from planktons biomass. In addition, the increased sedimentation rates could be also attributed to the long water residence time [15]. The Chaohu Dam, built in 1962, blocked the natural connection with the Changjiang River, which greatly reduced water exchange and increased water residence times to promote sediments and N retention in the Chaohu Lake sediment.

Acknowledgments

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