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Effects of pH and *Eh* on release of nitrogen and phosphorus from sediments of West Lake*

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Abstract: The effects of pH and *Eh* on release of nitrogen and phosphorus from sediments of West Lake under different conditions were investigated by simulation test. Results showed that the net flux of NH_4^+-N release from sediments increased with pH, but NO_3^--N showed negative-going release at all tested pH levels. The net flux of NH_4^+-N release from sediments was higher under anaerobic or aerobic condition of the overlying water, but only under aerobic condition would net release of NO_3^--N occur. It was also shown that phosphorus released was mainly in its inorganic form, higher pH and anaerobic conditions of overlying water greatly stimulated release of phosphorus. In situ measurement at several West Lake locations indicated that sediment resuspension induced by boat propeller stimulated nutrients release from sediment into overlying water.

Key word: West Lake, Sediments, Nitrogen, Phosphorus
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INTRODUCTION

As a sink and an inner source of nutrients, sediments play an important role in lake eutrophication. The eutrophication status of West Lake is still critical in recent years even after most pollution sources around West Lake have been controlled (Pei *et al*., 1998), mainly through the release of nutrients such as nitrogen and phosphorus from sediments (i.e., inner loading). This paper discusses the effects of pH and *Eh* on release of nitrogen and phosphorus from sediments of West Lake as revealed by simulation test. Results can serve as theoretical basis for water quality management and protection of West Lake.

MATERIALS AND METHODS

Sampling

Sediment samples were collected from the upper layer (0 – 20cm) of sediments in the center of West Lake using a net sampler (string bag with very small mesh), and a core sediment sample was collected with a special sampler (ϕ10 cm × 50 cm). Overlying water samples were also collected.

Sample preparation

After overnight settlement of the sediment samples, the water layer was then decanted. The core sediment sample was kept in its original form in a glass column. The overlying water was filtered with 0.45 μm membrane.

Effect test on release of N and P

A 350 g (fresh weight) sample of sediments was placed into a 2500 mL flask, into which 1500 mL filtered lake water was carefully poured along the flask wall. The pH and *Eh* of water overlying sediments were adjusted for tests on the release of N and P under different conditions (pH: 7.0, 8.0, 9.0; aerobic: $Eh > 250$ mV, general: $Eh = 200$ mV, anaerobic: $Eh < 100$ mV). The test lasted for about 16 weeks.

In situ measurement

Five sites (Duanqiao, Lake Yue, Huagang Dock, Changqiao, Lake center) of West Lake

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were chosen to test the effects of stirring by boat propeller on the release of N and P. After sampling the overlying water at five sites, we drove the boat turn around every sampling site for 10 minutes, then took samples again.

Analysis

The quantitative analysis was as follows: total organic matter (OG) with Tyurin method; total nitrogen (TN) with Kjeldahl digestion method; ammonia nitrogen (NH_4^+-N) with colorimetric method; nitrate (NO_3^--N) with ion chromatography method; dissolved total phosphorus (DTP) with colorimetric method; other species of phosphorus (i.e., Ca-P, NH_4F-P, NaOH-P and Reductive-P, Organic-P) with soil analysis method described in literature(CCSSSC, 1993).

RESULTS AND DISCUSSION

Effects of pH and *Eh* on release of NH_4^+-N and NO_3^--N from sediments

1. Effects of pH on release of NH_4^+-N and NO_3^--N from sediments

Fig.1 and Fig.2 of the temporal changes of NH_4^+-N and NO_3^--N concentration in overlying water at different pH levels show that the concentration of NH_4^+-N in overlying water decreased at pH 7.0, but increased at pH > 8.0, which could mainly relate to the rate of nitrification and diffusion of NH_4^+-N. Higher pH condition enhanced production of NH_3. The concentration of NO_3^--N decreased at all tested pH levels, implying that the rate of nitrification in overlying water was less than that of diffusion of NO_3^--N to sediments. These results implied that the NO_3^--N release mainly depended on *Eh* rather than pH.

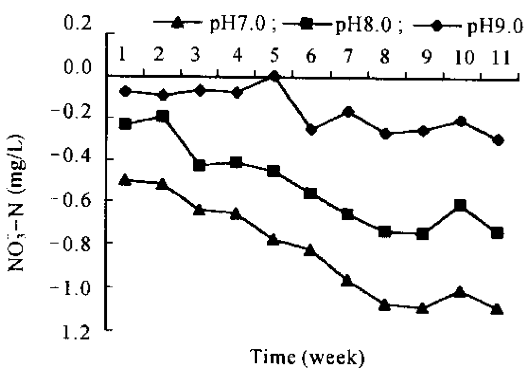

Fig.1 Concentration of NH_4^+-N in overlying water at different pH levels

The net fluxes of NH_4^+-N and NO_3^--N released from sediments calculated from Fig. 1 and Fig.2 are listed in Table 1.

Table 1 The net fluxes of NH_4^+-N and NO_3^--N at different pH levels (mgN/m²·d) *Eh* = 200 mV

Index	pH = 7.0	pH = 8.0	pH = 9.0
NH_4^+-N	1.17	2.11	2.57
NO_3^--N	−1.00	−0.85	−0.29

• Effects of *Eh* on release of NH_4^+-N and NO_3^--N from sediments

2. Effects of *Eh* on release of NH_4^+-N and NO_3^--N from sediments

The temporal changes of NH_4^+-N and NO_3^--N concentration in overlying water (pH = 8.5) at different *Eh* levels are shown in Fig.3 and Fig.4.

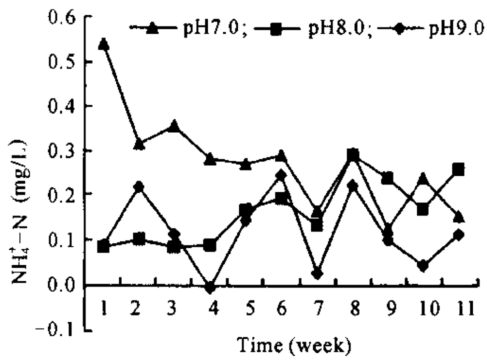

Fig.2 Concentration of NO_3^--N in overlying water at different pH levels

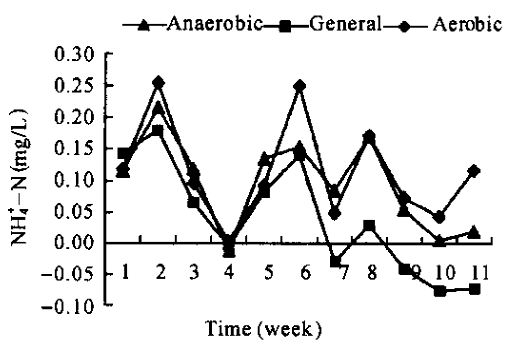

Fig.3 Concentration of NH_4^+-N in overlying water at different *Eh* levels

In general, the concentration of NH_4^+-N in overlying water tended to decrease regardless of anaerobic or aerobic conditions. The significant

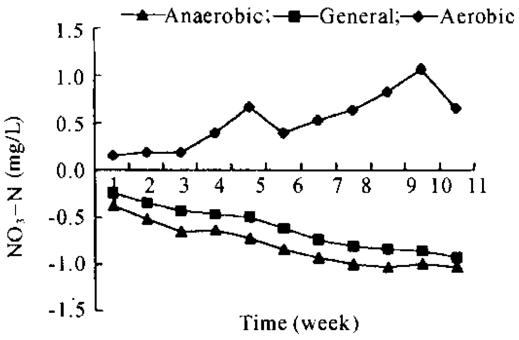

Fig.4 Concentration of NO_3^--N in overlying water at different *Eh* levels

fluctuation observed could be due to volatilization of NH_3. The concentration of NO_3^--N in overlying water changed distinctly with *Eh*; increased under aerobic condition but decreased under anaerobic or general *Eh* condition while denitrification played a main role in affecting NO_3^--N concentration.

The net fluxes of NH_4^+-N and NO_3^--N release from sediments calculated from Fig.3 and Fig.4 are listed in Table 2.

Table 2 The net flux of NH_4^+-N and NO_3^--N at different *Eh* levels (mgN/m²·d) pH = 8.5

Index	Anaerobic (*Eh* < 100 mV)	General (*Eh* = 200 mV)	Aerobic (*Eh* > 250 mV)
NH_4^+-N	1.99	1.17	2.13
NO_3^--N	−0.88	−0.92	3.60

The net fluxes of NH_4^+-N release from sediments under anaerobic or aerobic conditions were higher than that under general conditions. It is possible that NH_4^+-N diffused into overlying water could not be nitrified due to lack of oxygen in water. Under the aerobic conditions in overlying water, nitrate action promoted NH_4^+-N diffusion from interstitial water of sediments. Only under aerobic conditions would net flux of NO_3^--N occur.

In general, the concentrations of NH_4^+-N in overlying water mainly depend on diffusion and release of NH_4^+-N from interstitial water of sediments; and that of NO_3^--N mainly depend on nitrate action and diffusion from overlying water to sediments (VanLuijn *et al*., 1999).

Effects of pH and *Eh* on release of phosphorus from sediments

1. The form of phosphorus in sediments of West Lake

The chemical fractionation of phosphorus is shown in Fig.5. The organic form of phosphorus in sediments of West Lake accounts for 53.8% of total phosphorus, followed by the Ca-P form of phosphorus (18.6%). The dissolved form of phosphorus is only minimal (only 0.4%) (Li *et al*., 1999).

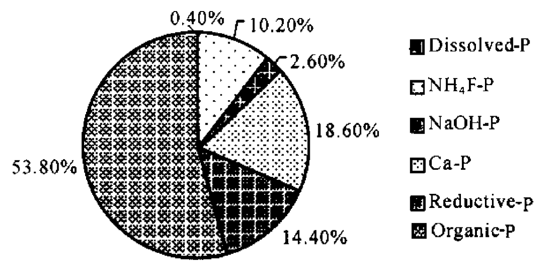

Fig.5 Phosphorus chemical fractionations in sediments of West Lake

2. Effects of pH on release of phosphorus from sediments

Fig.6 of the effects of pH on release of dissolved total phosphorus (DTP) shows that release of DTP differed little at different pH levels

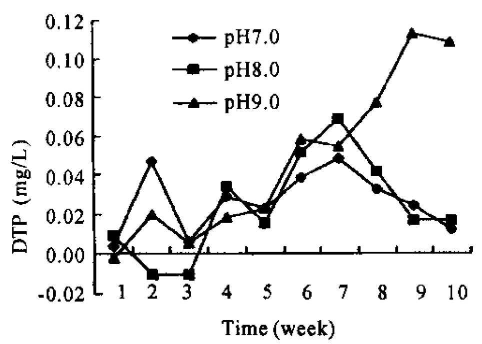

Fig.6 Concentration of DTP in overlying water at different pH levels

in the earlier seven weeks of the test; but that later, the concentration of DTP in overlying water peaked at pH 9.0 and decreased at lower pH. This maybe due to the reaction of OH^- with phosphorus adsorbed on the surface of Fe or Al oxide/hydroxide, Which could promote release of phosphorus from sediments at higher pH condition (Tang, *et al*., 1999).

The net flux of DTP release from sediments of West Lake listed in Table 3 shows that it was higher at higher pH levels.

Table 3 The net flux of DTP at different pH levels (mgN/m²·d) *Eh* = 200 mV

Index	pH = 7.0	pH = 8.0	pH = 9.0
DTP	0.02	0.02	0.13

3. Effects of *Eh* on release of phosphorus from sediments

The status of DTP release from sediments of West Lake at different *Eh* levels is shown in Fig.7. It is apparent that the concentration of DTP in overlying water changed very little under aerobic and general oxygen supply conditions; but increased under anaerobic condition in the earlier six weeks of test and then decreased somehow in the later weeks of the test. It implies that the release of phosphorus from sediments of West Lake mainly depends on the redox status at the sediment interface; and that the release mechanism of phosphorus may be related to the formation of Fe-P (Eckert *et al*., 1997). As to lakes which release of phosphorus controlled by Fe, substituting for the diffusion from reductive layers, the reaction of adsorption and deposition would become the main process of controlling the exchange of phosphorus under aerobic condition (Wang *et al*., 1996; Moore *et al*., 1998).

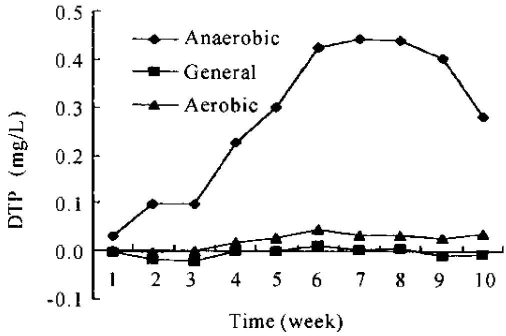

Fig.7 Concentration of DTP in overlying water at different *Eh* levels

The net flux of DTP release from sediments of West Lake listed in Table 4 shows that only under anaerobic condition the DTP would release from sediments.

Table 4 The net flux of DTP at different *Eh* levels (mgN/m²·d) pH = 8.5

Index	Anaerobic (*Eh* < 100 mV)	General (*Eh* = 200 mV)	Aerobic (*Eh* > 250 mV)
DTP	0.35	−0.01	−0.04

Effects of stirring by boat propeller on the release of nitrogen and phosphorus from sediments

For shallow lakes, the resuspension of sediments is an important pathway of nutrients release from sediments into overlying water. The measured in situ release of NH_4^+-N, PO_4^{3-}-P and DTP before and after stirring by propeller of boat is shown in Fig.8.

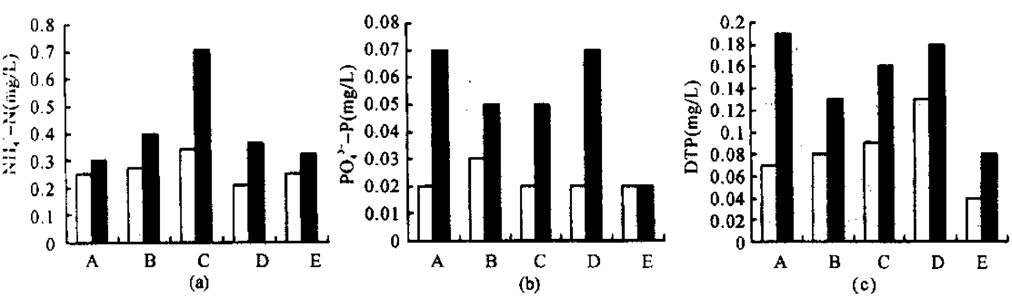

Fig.8 Effects of stirring by boat on release of (a) NH_4^+-N, (b) PO_4^{3-}-P and (c) DTP

A: Duanqiao; B: L. Yue; C: D. Huagang; D: Changqiao; E: Lake centre

□ before stirring; ■ after stirring for 10 min

We can see that the stirring by propeller of boat stimulates N, especially P release from sediment into overlying water. The difference among various measuring sites depends on the depth of water and other factors. It should be noted that the effect of stirring by boat propeller on the release of phosphorus was temporary; a steady state will be reached between resuspension and deposition of the resuspened sediments after some times (Fan, 1995).

CONCLUSIONS

The simulation tests showed that the net flux of NH_4^+-N in overlying water increased with pH, but NO_3^--N showed negative-going release at all tested pH levels. The net flux of NH_4^+-N release from sediments was higher under anaerobic or aerobic condition of the overlying water, but only under aerobic conditions would net flux of NO_3^--N occur. This implied that the release of NO_3^--N mainly related to *Eh* not pH.

Higher pH (pH > 8.5) and anaerobic conditions of overlying water greatly stimulate release of phosphorus. Sediment resuspension induced by boat propeller stirring also stimulate nutrients (N, P) release from sediments into overlying water.

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