The effect of aerating to sediment on phosphorus adsorption capacity and phosphorus forms in the sediment

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Abstract: The enhancement on phosphorus adsorption onto sediments and the effect on the phosphorus forms in the sediments by aerating to sediment were investigated, using sediments from the campus canal as material. The results show that aerating to sediment facilitates to the migration of phosphorus from overlying water to sediments and the enhancement was more evident than that by aerating to water. The phosphorus adsorption capacity of sediments after aerated was enhanced. Aerating to sediment obviously enhanced the accumulative adsorption quantity of phosphorus, higher than that by aerating to water. The main reason of it could be associated with the organic matter removal. Aerating to sediment would enhance the transformation from potentially mobile phosphorus to refractory forms in the sediments. The enhancement to this transformation by aerating to sediment was more evident than that by aerating to water.

Key words: phosphorus; adsorption; phosphorus forms; aerating to sediment
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1 Introduction

Phosphorus has been shown to be a major nutrient controlling eutrophication in many aquatic systems. External loading is controlled successfully, but the release of phosphorus from surface sediments supports the trophic status of the water[1-5]. To control the release of phosphorus in sediments has been paid more and more attention in recent years. Some studies have found that different natural sediments have different ability to adsorb phosphorus in the overlying water, but the ability to assimilate phosphorus depends on physical, chemical characteristics of each sediment. Other studies have examined the interactions of dissolved phosphorus with specific sediment components- for example Parfitt et al[6] boked at the sorption to iron oxides; Bar-Yosef et al[7] at the sorption to kaolinite and montmorillonite; and Al-Kanani and MacKenzie[8] at sorption to goethite and kaolinite. Natural sediments are composed of a different combination of minerals, such as Fe_{ox}, Al_{ox}, hydroxy clay mineral. The capacity of phosphorus adsorption onto sediments has been attributed to all these components in sediments.

It was found[9] the formation of ferric hydroxide with associated high-energy sorption sites was promoted after the organic matters in the sediments were oxidized. Moreover, with the anaerobic sediment being transferred to aerobic conditions, Fe(II) was oxidized to Fe(III)[10] at the same time. Fe(III) can adsorb a large quantity of phosphorus by forming Fe(OOH)—P complexes or precipitates, such as $\{Fe(PO_4)_x(OH)_{3-x}\}$[11]. It was reported

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that most of phosphorus adsorbed is associated with amorphous and poorly crystalline forms of Fe and Al and readsorption by Fe and Al oxides provides long-term phosphorus storage[12]. This facilitates to reduce the release of phosphorus from the sediments. It was known that the phosphorus which were adsorbed could be transformed into some special phosphorus forms. As a result, the distribution of phosphorus forms was changed due to the aerating which promoted the sediment re-suspension. Correspondingly, the release of phosphorus from the sediment after aerated may be different from the sediment without aeration. But so far, infromation concerning phosphorus adsorption capacity of the sediment and the transformation of phosphorus forms in the sediment by aerating to sediment to remove the organic matter is not possible to obtain.

This paper reports results from laboratory studies in which sediments from campus canal were aerated under re-suspension conditions. The enhancement of phosphorus adsorption on the sediments after aerated and the effect on the distribution of phosphorus forms in the sediments after aerated were investigated.

2 Materials and methods

2.1 Routine sampling

The sampling site is at the inlet of the canal in the university of science and technology of suzhou. Sediments, taken from the top layer (0 ~ 3 cm), were stored in capped glass flasks(4 ℃) and then transported to laboratory immediately. After removing the large debris, the sediment samples were homogenized and stored in air tight flasks at 4 ℃ until use. The characteristics of the sediment were shown in table 1.

Table 1　Basic properties of the sediment

properties	pH	TP/mg·kg^{-1}	Water content	Organic content
data	6.62	728.55	83.69%	13.23%

2.2 Experimental set-up

(1) Aerating experiment: three sets of perspex containers(named E1 and E2 and E3), 154 mm diameter × 300 mm high, were used as the reaction chambers for the simulation experiments; each set including three parallel containers. The sediment samples (200 g net weight) were loaded carefully into the champers. River water (2.5 L) collected from the sampling site was very carefully filled in the champers, not disturbing the sediments. For E1, sediments were aerated using a commercially available aerator at the rate of 25 L·min^{-1} for 10 min·d^{-1}, and the sediments were suspended completely. For E2, overlying water was aerated using a commercially available aerator at the rate of 25 L·min^{-1} for 10 min·d^{-1}, and the sediments were not suspended completely. For E3, no any treatment was used on the sediment and water, so the sediment was not suspended comletely, being the control experiment. The experiments were started (day 0), and then intermittent monitoring of soluble reactive phosphorus (SRP) in the overlying water was conducted.

Over 29 days, the sediments were obtained from each chamber. They were dried, ground and then sieved with a standard 100 mesh sieve. The sediments from E1, E2 and E3 were named ES1, ES2, ES3, respectively. The raw sediments were named ES0.

(2) Phosphorus adsorption experiments: an amount of 0.50 g dried sediment sample was put in 100 mL test tubes containing 50 mL water collected from the river and five parallel samples were started. The tubes were incubated at(25 ±1) ℃ in an reciprocating shaker at 180 ~ 190 r·min^{-1} for 24 h. After equilibrium and centrifuation (3500 r·min^{-1} for 20 min), the equilibrium phosphate concentration (SRP) and total phosphorus(TP) concentration were analyzed. Based on the difference between the initial phosphate concentration and the equilibrium phosphate concentration and blank controls, the adsorption rate of phosphate was calculated, and the adsorption rate of TP was calculated as the same. The residual in the test tubes was continuously used to adsorb phosphorus in the water in order to reveal the ability of sediments after aerated to adsorb phosphorus sequentially. The steps above-mentioned were repeated. The adsorption experiments were repeated 4 times.

2.3 Chemical analysis

The forms of phosphorus were determined on dry samples by extracting phosphorus according to the scheme of Rydin[13]. Sediment and extracted solution were separated through a centrifugal machine(4 000 r·min^{-1} for 20

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min). The solid phase was used for the next extracting procedure and the solution was filtered through 0.45 μm polyamide filter for subsequent PO_4^{3-} analysis. Sedimentary phosphorus was separated into (a) NH_4Cl– P (loosely phosphorus); (b) BD– P(phosphorus absorbed to iron and manganese); (c) Al– P (phosphorus exchangeable with OH^-, mainly aluminium); (d) NaOH – nrP(organic– P, including bacteria– incorporated phosphorus); (e) Ca– P(phosphorus forms sensitive to low pH, assumed to consist mainly of apatite); (f) Residual– P (consisting mainly of refractory organic phosphorus as well as the inert inorganic phosphorus fraction). TP was the sum of all phosporus forms.

Percentage water content(wt/wt) was analyzed by loss on drying at 105 ℃ for 12 h. Dried samples were then incinerated at 550 ℃ in a muffle furnace for 2.5 h to determine the percentage ash free dry weight.

3 Results and discussion

3.1 The effect of aerating on the migration of phosphorus in overlying water

Fig. 1 and Fig. 2 showed the variation of phosphorus in overlying water during the process of aerating.

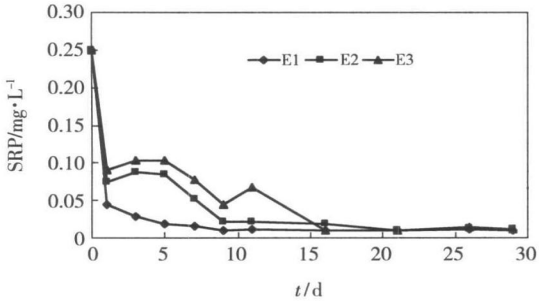

Fig. 1 The variation of SRP concentrations in the overlying water

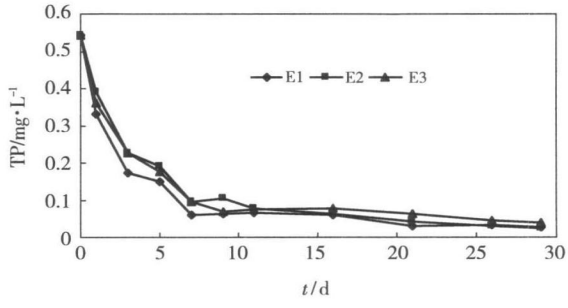

Fig. 2 The variation of TP concentrations in the overlying water

The SRP concentrations, in all simulation tests, lie in the range of 0.010 mg• L^{-1} to 0.104 mg• L^{-1} in the overlying water of the reaction champers and are shown in Fig. 1. It was found that all the SRP concentrations were reduced sharply at the next day. SRP release in E2 and E3 was found at the 3rd day, however, no SRP release in E1. The equilibrum state of SRP in the overlying water was reached after 9d for E1(0.011 mg• L^{-1}), lower than the control experiment(0.016 mg• L^{-1}), however, in E2 the equilibrium state of SRP was reached after 16 d, 0.026 mg• L^{-1}. It was indicated that sediment re– suspension could promote phosphorus migration from overlying water to the sediment. The main reason of it could be that the formation of Fe_{ox} and Al_{ox} was enhanced due to sediment re– suspension[14–15] and the inorganic matters, such as Fe_{ox}, Al_{ox} and hydroxy clay minerals were increased in the overlying water. The TP concentrations are shown in Fig. 2. In E1, E2, E3, TP appeared to decrease slightly at the next day and no increase was found within 29 days. The TP content in E1 was lower than that in E2 and E3. At the seventh day, the TP content in E1, E2 and E3 was kept relatively constant, 0.048 mg• L^{-1}, 0.063 mg• L^{-1}, 0.067 mg• L^{-1}, respectively. It was shown that sediment re– suspension facilitates the migration of phosphorus from overlying water to sediments.

3.2 Phosphorus adsorption onto sediments after treated by aerating

Aerating to sediment may influence the phosphorus adsorption onto the sediment, as shown in Fig. 3 and Fig. 4. Fig. 3 shows that the accumulative adsorption quantity of SRP on different sediments was increased with time. It was found that the phosphorus adsorption capacity of ES1 was higher than that of other sediments. The SRP adsorption rate of different sediments was the greatest, up to 1.192~ 1.292 mg• $(kg• h)^{-1}$, at 0~ 24 h and then gradully was decreased with time. Moreover, the rate was about 9 times higher than that of at 96~ 120 h. The average SRP adsorption rate on different sediments(ES0, ES1, ES2, ES3) was 0.653 mg• $(kg• h)^{-1}$, 0.781 mg• $(kg• h)^{-1}$, 0.631 mg• $(kg• h)^{-1}$, 0.683 mg• $(kg• h)^{-1}$, respectively. The accumulative adsorption of TP on different sediments

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followed the same trend as SRP(Fig. 4). Fig. 4 revealed that the ability of ES1 to adsorb TP was better than that of other sediments and the greatest accumulative adsorption amount was up to 137.92 mg·kg^{-1}, while the greatest accumulative adsorption amount of other sediments(ES0, ES2, ES3) was 82.18mg·kg^{-1}, 114.18 mg·kg^{-1}, 116.95 mg·kg^{-1}, respectively. In the experiment, it was found that TP in ES0 appeared to release within 96 h to 120 h and the release was up to 21.4 mg·kg^{-1}, but no release in other sediments was found.

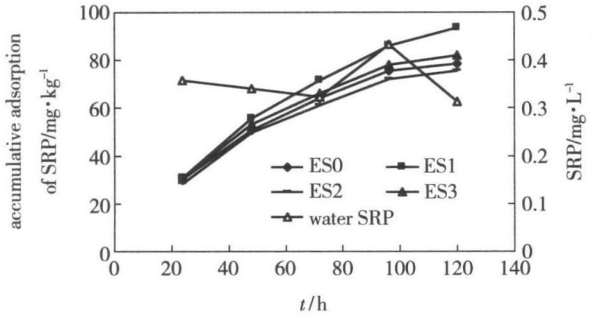

Fig. 3　Accumulative adsorption of SRP onto sediments by aerating

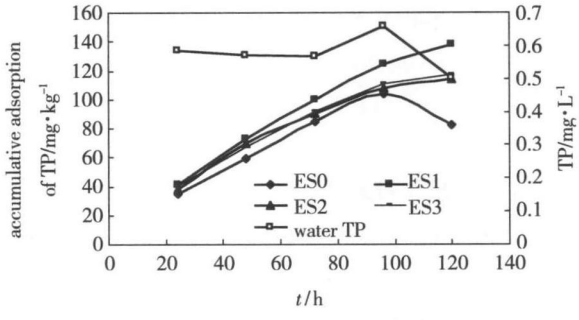

Fig. 4　Accumulative adsorption of TP onto sediments by aerating

It was found that the ability of ES1 to adsorb phosphorus was better than that of other sediments. The main reason of it could be as followed: ① the organic matter removal due to aerating to sediments. In the experiment, the organic content of ES1, ES2 and ES3 was decreased from 13.23% (ES0) to 9.51%, 11.98%, 12.36%, respectively. Due to the organic matter removal, the physical-chemical characteristics of sediments was changed and the high-energy sorption sites, such as Fe_{ox} and Al_{ox}, were increased at the same time. ② the distribution of phosphorus forms was varied sharply due to sediment re-suspension which promoted the transformation of phosphorus from potential mobile forms to refractory forms.

3.3　Effect on the phosphorus forms in sediments by aerating

In table 2, the distribution of phosphorus forms in different sediments is compared. There was an increase in TP content in the sediments, compared with that in raw sediments, showing that phosphorus was incorporated into sediments from the overlying water during the aerating. It was found that there were drastic changes in the phosphorus composition in different sediments. The phosphorus in all sediments chiefly consisted of BD-P, Ca-P, Al-P and NH_4Cl-P, Res-P, NaOH-nrP constituted a minor part, which accounted on average for 57.28%, 13.41%, 12.41% and 7.08%, 5.35%, 4.47% of TP, respectively. The concentration of NH_4Cl-P was decreased in ES1, while it was increased in ES2 and ES3, compared with ES0. The concentrations of BD-P, Ca-P, Al-P were increased in ES1, while they were kept relatively constant in ES2 and ES3. NaOH-nrP was increased in different sediments. Generally, sediment re-suspension could improve BD-P release, while BD-P was increased in ES1. Obviously, there was contradiction. This associated with the accumulation of Fe_{ox} because of the DO increase under sediment re-suspension. Phosphorus could be adsorbed or complexed with Fe_{ox}, therefore, BD-P was increased. Moreover, readsorption by Fe_{ox} provides long-term phosphorus storage[12], showing that sediment re-suspension could enhance phosphorus retention. In ES1, the net increase of Ca-P was up to 36.8 mg·kg^{-1}, higher than that of raw sediments, indicating that sediment re-suspension could promote the formation of Ca-P. This was attributed to the increase of contact probability between the ion of Ca and PO_4^{3-} in the overlying water under the conditions of sediment re-suspension.

Table 2　Variation of phosphorus forms of different sediments

Item	sediment			
	ES0	ES1	ES2	ES3
TP/mg·kg^{-1}	728.55	797.48	751.71	738.42
NH_4Cl-P/mg·kg^{-1}	51.85	44.45	61.41	62.03
BD-P/mg·kg^{-1}	430.83	457.48	415.41	416.76
Al-P/mg·kg^{-1}	90.76	100.62	89.30	94.23
NaOH-nrP/mg·kg^{-1}	20.50	24.89	50.35	36.60
Ca-P/mg·kg^{-1}	92.76	129.56	92.76	89.83
Res-P/mg·kg^{-1}	41.85	40.48	42.48	38.97

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As well known, NH_4Cl-P, BD-P and NaOH-nrP were considered potentially mobile phosphorus (PMP)[13]. In the experiment, it was found that the concentrations of PMP in ES0, ES1, ES2, ES3 was 69.06%, 66.06%, 70.13% and 70.59% of TP, respectively. It was showed that the contribution of PMP to TP was decreased in ES1, compared with that in ES0, while the value in other sediments was kept relatively constant. It was suggested that sediment re-suspension could enhance the transformation of phosphorus from potential mobile forms to refractory forms. It is benefical for permanent burial of phosphorus. But in the sediments from aerating to water and the control experiment, PMP/TP was increased slightly, compared with that in raw sediments, showing that phosphorus could be transformed into PMP at the first step with phosphorus migrating from overlying water to sediments.

4 Conclusions

(1) Aerating to sediment could promote the migration of phosphorus from overlying water to sediments, and the enhancement was better than that by aerating to water.

(2) Aerating enhanced the phosphorus adsorption capacity of phosphorus on sediments, but the enhancement by aerating to sediment was more evident than that by aerating to water. This was likely attributed to the organic matter removal.

(3) The distribution of phosphorus forms in different sediments was changed obviously. Aerating to sediment would enhance the transformation from potentially mobile phosphorus to refractory forms in the sediments. Then enhancement to this transformation by aerating to sediment was more evident than that by aerating to water.

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References

[1] WALLBRINK P J, MARTIN C E, WILSON C J. Quantifying the contributions of sediment, sediment-p and fertilizer-p from forested, cultivated and pasture areas at the landuse and catchment scale using the fallout radionuclides and geochemistry[J]. Soil and Tillage Research, 2003, 69: 53-68.

[2] JIN X C, WANG S R, PANG Y, et al. The adsorption of phosphate on different trophic lake sediments[J]. Collides and Surfaces, 2005, 254: 241-248.

[3] APPAN A, TING D S. A laboratory study of sediment phosphorus flux in two tropical reservoirs[J]. Wat Sci Tech, 1996, 34: 45-52.

[4] DIEDERIK T. VAN DER MOLEN, PORTIELJE R, et al. Changes in sediment phosphorus as a result of eutrophication and oligotrophication in lake Veluwe, the Netherlands[J]. Wat Res, 1998, 32: 3281-3288.

[5] EDLUND G, CRAMAN R. Distribution and diagenesis of organic and inorganic phosphorus in sediments of the Baltic proper[J]. Chemosphere, 2001, 45: 1053-1061.

[6] PARFITT R L, ATKINSON R J, SMART R S T C. The mechanism of phosphate fixation by iron oxides[J]. Soil Sci Soc Am Proc, 1975, 39: 837-841.

[7] BAR-YOSEF B, KAFKAFI U, ROSENBERG R, et al. Phosphorus adsorption by kaolinite and montmorillonite[J]. Effect of time, ionic strength, and pH[J]. Soil Sci Soc Am J, 1988, 52: 1580-1585.

[8] AL-KANANI T, MACKENZIE A F. Sorption and desorption of orthophosphate and pyrophosphate by mineral fractions of soils, goethite, and kaolinite[J]. Can J Soil Sci, 1991, 10: 329-331.

[9] HOUSE W A, DENISION F H. Factors influencing the measurement of equilibrium phosphate concentrations in river sediments[J]. Wat Res, 2000, 34(4): 1187-1200.

[10] PENG J F, WANG B Z, SONG S H, et al. Adsorption and release of phosphorus in the surface sediment of a wastewater stabilization pond[J]. Ecological Engineering, 2007, 31(2): 92-97.

[11] ZAK D, GELBRECHT J. Phosphorus retention at the redox interface of peatlands adjacent to surface waters[J]. Wasser and Boden, 2002, 54: 71-76.

[12] REDDY K R, FLAIG E G, GRAETZ D A. Phosphorus storage capacity of uplands, wetlands, and streams of the lake Okeechobee Watershed, Florida[J]. Agriculture Ecosystems and Environment, 1996, 59: 203-216.

[13] EMIL RYDIN. Potentially mobile phosphorus in lake erken sediment[J]. Wat Res, 2000, 34: 2037-2042.

[14] SAKADEVAN K, BAVOR H J. Phosphate adsorption characteristics of soils, slags and zeolite to be used as substrates in constructed wetland systems[J]. Wat Res, 1998, 32(2): 393-399.

[15] MCCALLISTER D L, LOGAN T J. Phosphate adsorption-desorption characteristics of soil an bottom sediments in the Maumee River Basin Ohio[J]. J Environ Qual, 1978, 7: 87-92.

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– 200.
[8] GRAHAM JH. What do root pathogens see in mycorrhizas? [J]. New Phytologist, 2001, 149: 357– 359.
[9] LI S, KENT T A. Camptotheca acuminata Decaisne XISHU (Chinese Happy Tree) a promising Anti– tumor and Anti– viral tree for the 21st century[C]. Texas: The Tucker Center Collage of Forestry Stephen F. Austin State University, 1994.
[10] 赵 昕, 阎秀峰. 丛枝菌根对喜树幼苗生长和氮、磷吸收的影响[J]. 植物生态学报, 2006, 30(6): 947– 953.
[11] 赵 昕, 王博文, 阎秀峰. 丛枝菌根对喜树幼苗喜树碱含量的影响[J]. 生态学报, 2006, 26: 1057– 1062.
[12] PHILLIPS JM, HAYMAN D S. Improved procedures for clearing and attaining parasitic and vesicular– arbuscular mycorrhizal fungi for rapid assessment of infection[J]. Transactions of the British Mycological Society, 1970, 55: 158– 161.
[13] TROUVELOT A, KOUGH JL, GIANINAZZI– PEARSON V. Mesure du taux de mycorrhization VA d' un systeme radiculaire– Recherche de methods destination ayant use signification fonctionelle[C]. GIANIAZZI– PEARSON V, GIANIAZZI S. Physiology and Genetics Aspectes of Mycorrhizae. Paris: INRA Press, 1986: 217– 221.

Mycorrhizal colonization of *Camptotheca acuminata* seedlings inoculated with three arbuscular mycorrhizal fungi

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Abstract: *Camptotheca acuminata* seeds were sown in sterilized sands in the greenhouse. After 35– day growth, seedlings were inoculated with three species of arbuscular mycorrhizal fungi (AMF), *Acaulospora mellea*, *Glomus diaphanum*, and *Glomus intraradices*. Mycorrhizal colonization of *C. acuminata* seedlings inoculated with AMF were investigated. The results showed that mycorrhizal colonization frequency, root mycorrhizal colonization intensity, arbuscular abundance and vesicle abundance increased with the growth of *C. acuminata* seedlings and the increase of days after inoculating with arbuscular mycorrhizal fungi. Compared with others, *Acaulospora mellea* mycorrhizal fungi was easier to infect *C. acuminata* seedlings and to form arbuscular and vesicle.

Key words: *Camptotheca acuminata* seedlings; arbuscular mycorrhiza; colonization

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底泥曝气对磷吸附容量和底泥中不同形态磷含量的影响

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摘 要: 研究了底泥曝气对底泥吸附磷的强化作用以及对底泥中不同形态磷数量分布的影响, 底泥采自校园河流。结果表明: 底泥曝气有利于上覆水中磷向底泥迁移, 并且, 这种促进作用优于对水曝气。底泥曝气后, 底泥对磷的吸附容量显著增加。底泥曝气显著增加了磷的累计吸附量, 并高于对水曝气。原因可能与有机物去除有关。底泥曝气可以强化潜在活性磷向难释放态磷转化, 这种强化作用高于对水曝气。

关键词: 磷; 吸附; 磷形态; 底泥曝气

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