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Sedimentation Rate in Enclosures with Various Densities of *Eichhornia crassipes* in Wulihu, Taihu Lake, China*

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Abstract: *The dynamic model of physical-biological engineering for purifying water quality in Lake Taihu needs the parameter of sedimentation rate (SR). Especially, it is seldom reported how SR is influenced by interactions between algae and aquatic plant. So 6 enclosures with each area of 5×5 m^2 were constructed in Wulihu with 2 m depth, a small hypereutrophic bay of Taihu Lake, China. Enclosures, in which the original water quality was the same as that in surrounding lake, were input Eichhornia crassipes at various original densities from 0-6 kg·m^{-2} on August 9, 1996. SR had been measured separately at depths of 0.6, 1.2,1.8 m in each enclosure during 20 days. Main results were as follows: 1) SR average in enclosures (17.3g·m^{-2} d^{-1}) was as much as about 1/14 that in the surrounding lake; 2) The deeper was it, the higher rate was it in each enclosure, generally; 3) SR cures versus original densities of Eichhornia crassipes (ODE) in enclosures had the ship of "V" at different depths; SR minimuma were observed in the enclosure with original meso-density of Eichhornia crassipes (EMESO, 4kg·m^{-2}), the average of SR minimuma was about 8.55 g ·$m^{-2}d^{-1}$; 4) SR in enclosures with original hypo-density (EHYPO, 0-3kg·m^{-2}) were mainly negative related with water temperature and light intensity ;while those with original hyper-density (EHYPR, 5-6kg.m^{-2}) were mainly negative related with transparency (SD) instead.These SR-distribution characteristics may be explained by interactions between dead algae and relics of Eichhornia crassipes.*

Keyword: *Sedimentation rate, interactions between algae and Eichhornia crassipes, Taihu Lake*

1. Introduction

Many lakes are becoming progressive environmental deterioration (such as Lake Taihu), and a lot of cities are seriously short of drinking water because of pollution, so many researches have been made. However, the method how water quality can be improved gradually, continuously and inexpensively has not been found by now. An approach of physico-ecological engineering (PEEN) was developed (PU, P. *et al*, 1993, 1995). The PEEN improves water quality in local areas by the method of constructing artificial ecosystem and mainly using the solar energy. Some artificial ecosystems for purifying water in Lake Taihu had been carried out. The dynamic model of physical-biological engineering for purifying water quality in Lake Taihu needs the parameter of sedi-

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mentation rate (SR). The issue, whether the artificial ecosystem engineering accelerates the lake's being silted up or not, has not been settled. Especially, it is seldom reported how SR is influenced by interactions between algae and aquatic plant. So SR had been tested in Enclosures with Various Densities Of *Eichhornia crassipes* (EVDE) in Wulihu, Taihu Lake, China.

2. Material and Methods

Six enclosures with each area of 5×5 m^2 were constructed in WuLiHu Lake which is a small bay of Taihu Lake, China, with mean depth of 2 m. Enclosures (numbered northward as A#, B#, C#, D#, E#, F#), in which the original water quality was the same as that in surrounding lake (numbered as N#), were input *Eichhornia crassipes* at various original densities (separately 0, 2, 3, 4, 5, 6 kg · m^{-2}) on August 9, 1996. The suspending substance was collected in special-made bottles (the mouth inner diameter 55 mm, height 15 cm, volume 1 liter) respectively at upper water layer (UWL, 0.6 m deep), middle water layer (MWL, 1.2 m), lower water layer (LWL,1.8 m). The collecting periods were separately double 3 days (August 23 to 26, August 26 to 29), 4 days (August 29 to September 2), 7 days (August 11 to 18), 12 days (August 11 to 23). The sediment was firstly filtrated off water with Ø60 mm acetate fibre filter (0.45 μm), secondly stoved to constant weight at 105 °C for 4 hours in aluminum boxes in an oven, thirdly weighed in the balance with the precision of 1/10 000 gram, and lastly SR were calculated.

3. Results

3.1 SR contrast between in enclosures and in the surrounding lake

The data at different depths in various periods showed, that the maximum, minimum and mean value of SR in enclosures were 58.0 g·m^{-2}d^{-1}, 4.3 g·m^{-2}d^{-1} and 17.3 g·m^{-2}d^{-1}, respectively, while the same elements of SR in the surrounding lake were 430.0 g·m^{-2}, 90.6 g·m^{-2}d^{-1} and 239.7 g·m^{-2}d^{-1}, respectively. So SR in enclosures were as much as about 1/14 that in the surrounding lake. It showed that the artificial ecosystem engineering can slow down the lake's being silted up.

3.2 SR at different depth

When it became deeper in enclosures and in the surrounding lake in various periods, all SR increased. Suppose SR at MWL was 100 %, SR at UWL was average 16.54 % (minimum of 7.75 %, maximum of 21.37 %) less than that at MWL while SR at LWL was average 48.95 % (23.17 %, 91.16 %) more than that at MWL, i.e. SR minimuma appeared generally at UWL (Fig. 1, Tab. 1).

3.3 SR distribution verus ODE in enclosure

ODE increased gradually from 0→2→3→4→5→6 (kg·m^{-2}) northward in enclosures A#→ B#→ C#→ D#→ E#→ F#. All SR at different water layer in various periods decreased gradually with increasing of ODE to 4 kg·m^{-2}, and then increased gradually with increasing of ODE up to 6

Tab.1 Contrast of SR at different water layer in enclosures and in surrounding lake (%)*

No.	A#	B#	C#	D#	E#	F#	N#	Average
UWL(0.6m)	-19.79	-14.36	-14.49	-18.91	-7.75	-19.11	-21.37	-16.54
LWL(1.8m)	+44.08	+59.53	+39.75	+50.95	+91.16	+34.00	+23.17	+48.95

*Suppose SR at MWL was 100 %, + shows SR % more than that of at MWL (1.2m), – show SR % less than that of at MWL

$kg{\cdot}m^{-2}$. The mean SR in the enclosure with original hypo-density of *Eichhornia crassipes* (EHYPO, A# 26.7 $g{\cdot}m^{-2}d^{-1}$) was about the same as that in the enclosure with original hyper-density of *Eichhornia crassipes* (EHYPR, F# 25.2 $g{\cdot}m^{-2}d^{-1}$). The minimuma SR were observed in the enclosure with original mesodensity of Eichhorma crussipes (EMESO ,D#, the minimuma average about 8.5 $g{\cdot}m^{-2}d^{-1}$). In a short, all SR cures versus ODE had the ship of "V", and SR minimuma appeared in EMESO, so the SR minimuma appeared at UWL in EMESO (Fig. 1).

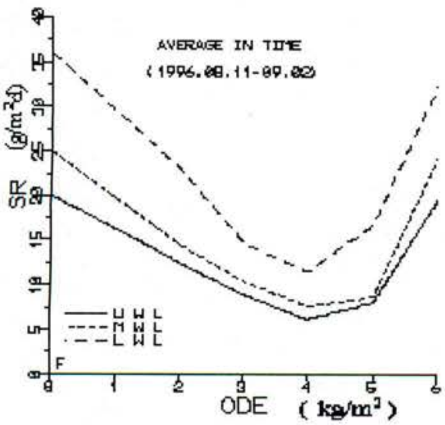

Fig. 1 SR cures versus ODE at different water layer in enclosures

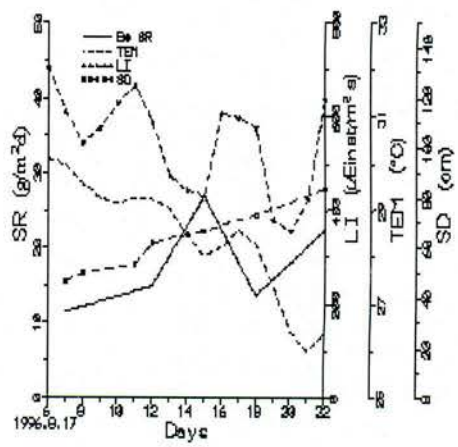

Fig. 2 Comparison between SR and LI, TEM, SD in B#

3.4 SR distribution in time

The time variation of the mean value of SR in the vertical profile has complex characteristics. But the curves of the maximum, minimum and amplitude (maximum-minimum) of SR versus ODE also had the ship of "V" in each enclosure and the minimuma appeared in EMESO too (Tab. 2).

Tab. 2 SR characteristic value in time (average at different water-layer)

No.	A#	B#	C#	D#	E#	F#	N#
ODE ($kg{\cdot}m^{-2}$)	0	2	3	4	5	6	
AVE ($g{\cdot}m^{-2}d^{-1}$)	29.02	17.85	11.87	8.55	11.48	26.63	271.12
MAX ($g{\cdot}m^{-2}d^{-1}$)	41.70	26.84	18.52	11.12	19.22	45.67	311.82
MIN ($g{\cdot}m^{-2}d^{-1}$)	19.43	11.44	8.72	7.39	5.56	14.33	234.93
MAX−MIN ($g{\cdot}m^{-2}d^{-1}$)	22.28	15.40	9.80	3.73	13.66	31.34	76.89

3.4.1 SR in EHYPO

After *Eichhornia crassipes* had been input, SD improved slowly and gradually in EHYPO (A#, B#, C#), but SR vibrated greatly (e.g. B#, SR Max-Min= 15.40 g·m^{2}d^{-1}, Table 2). SR in EHYPO was mainly negative related with water temperature TEM and light intensity(LI). SR rose generally, when air temperature dropped and light intensity reduced, and vice versus. For example, the SR in B# rose up from 19.7 to 26.8 g·m^{-2}d^{-1} during 23- 26 August, 1996 (for 12~15 days), while the light intensity dropped from 664.5 μEinst·m^{-2}s^{-1} to 441.7 μEinst·m^{-2}s^{-1}, and the water temperature fell down from 29.2 °C to 27.5°C in the period. The SR reduced from 26.8 g·m^{-2}d^{-1} to 13.7 g·m^{-2}d^{-1} during 26-29 August, 1996 (for 15~18days), while the light intensity increased from 431.0 μEinst·m^{-2}s^{-1} to 600.0 μEinst·m^{-2}s^{-1}, temperature went up from 28.0 °C to 29.0 °C(Fig2).

3.4.2 SR in EMESO

SR in EMESO increased only slightly (e.g. D#, SR Max-Min= 3.73 g·m^{-2}d^{-1}, Table 2). SR in EMESO was seldom related with water temperature, light intensity and SD (Fig. 3).

3.4.2 SR in EHYPR

SR in EHYPR vibrated greatly and was related with SD.

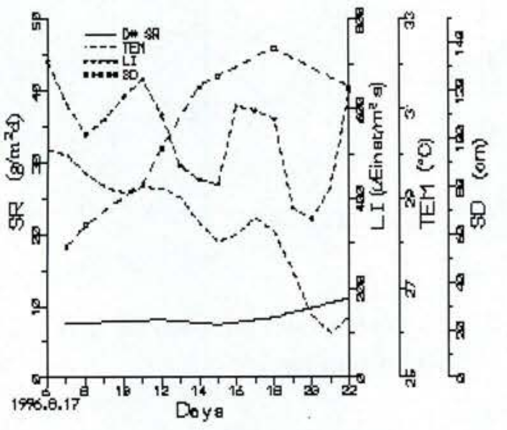

Fig. 3 Comparison between SR and LI, TEM, SD in D#

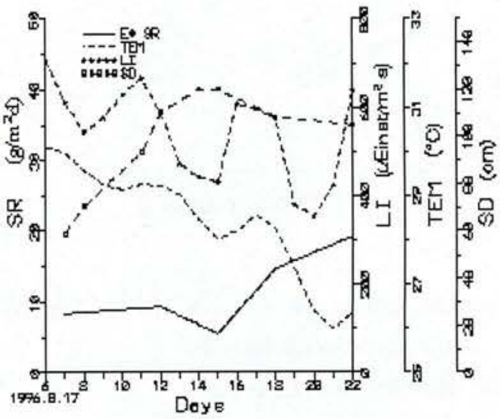

Fig. 4 Comparison between SR and LI, TEM, SD in E#

SD in each enclosure increased gradually after *Eichhornia crassipes* had been input. The more original density, the quicker SD improved. For example, in 15th day (August 23, 1996), SD in E# reached 130cm while SD in D# reached only 110cm and SD in B# was much less only 65 cm.

In EHYPR (E#, F#), SD improved quickly to the peak value then fell down, while SR, just the opposite, fell down gradually to the trough value and then increased gradually. SD maximuma were corresponding to SR minimuma. SD appeared positive vibrations, while SR showed negative vibrations. For example, in F#, on August 26,1997 (Days:15), SD reached maximuma

(120cm), meanwhile SR fell down to minimuma (5.55 $g{\cdot}m^{-2}d^{-1}$) ; from August 22 to 26 to 30, 1996(Days:11-15-19), SD changed from 93.3 to 120 to 108.3 cm (positive vibration), while SR varied from 9.45 to 5.55 to 14.76 $g{\cdot}m^{-2}d^{-1}$ (negative vibration). Moreover SR distributions in EHYPR in time were seldom related with temperature and light intensity (Fig. 4). In a word, SR in EHYPR was mainly negative related with SD.

4. Discussion

Rules on SR distributions are related with the living things in the water. Observations by microscope and with naked eye showed: deposits in EHYPO were mainly dead algae and their adsorbed colloidal clay, while those in EHYPR were mainly dead leaves and roots (from living *Eichhornia crassipes*) and a few feces (from small fishes and shrimps).

1) Because of rich nutrient, algae in the surrounding lake keep great breeding and death rate which results in a large number of dead algae and their adsorbed colloidal clay in the water, so it causes SR in the surrounding lake much higher than those in enclosures. *Eichhornia crassipes* assimilated a large amount of nutrient during its growth. If they can be removed, the artificial ecosystem engineering can slow down the lake's being silted up actually.

2) From the surface to the bottom, because of resuspension by wave or other things at the bottom and because of suspending-particle flux increase by gravitation of dead living things, SR increases from the thinner water to the deeper water.

3) When ODE increases in enclosures, it not only results in increasing concentration of their dead leaves and roots in the water and leading to rise up of SR by *Eichhornia crassipes*, but also results in declining algae density because of their poor competition and leading to decrease of SR by algae. So both actions cause SR distributions of showing the shape of "V" letter and SR in EMESO is the lest one.

4) Algae are more sensitive to water temperature and light intensity when the water temperature is at 32--25℃from the end of Summer to the beginning of Autumn, so their death rate becomes greater and their breeding rate lower when water temperature and light intensity falls down, it causes SR rising in EHYPO, vice versus. SR in EHYPO are mainly negative related with water temperature and light intensity.

Otherwise, *Eichhoria crasspies* in EHYPR grows quickly in the first period. The algae growth was weakened. This leads decrease of suspended substances and SR, and increase of SD. When time is going, because of growth restriction (space etc.), the concentration of relics of *Eichhoria crasspies* increases, it makes suspended substances and SR increase, and SD decrease. The more SD is it, the less relics of leaves and roots are suspended in water, the lower SR is it. So SR in EHYPR are mainly negative related with SD.

5) SR in EMESO has minimum and changes slightly, meanwhile SD in EMESO has maximum and water quality is best. These show EMESO has strong ability for anti-change of environment. Maybe water quality changes in a positive evolution in EMESO.

5. Conclusion

1) SR average in enclosures (17.3 $g\cdot m^{-2}d^{-1}$) was as much as about 1/14 that in the surrounding lake.

2) The deeper was it, the higher rate was it in each enclosure.

3) SR cures versus original densities of *Eichhornia crassipes* (ODE) in enclosures had the ship of "V" at different depths; SR minimuma were observed in the enclosure with original meso-density (EMESO, 4kg$\cdot m^{-2}$), the average of SR minimuma is about 8.55 $g\cdot m^{-2}d^{-1}$.

4) SR in EHYPO (0-3kg$\cdot m^{-2}$) were mainly negative related with water temperature and light intensity. SR in EHYPR (5-6kg$\cdot m^{-2}$) were mainly negative related with SD instead. However, SR in EMESO was seldom related with water temperature, light intensity and SD. EMESO had strong ability for anti-change of environment.

5) These SR-distribution characteristics may be explained by interactions between dead algae and relics of *Eichhornia crassipes*.

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