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A Model on a Physico-Biological Engineering Experiment for Purifying Water by using *Trapa natans var. bispinosa* in Wulihu Bay of Taihu Lake, China[*]

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Abstract: *A model on a physico-biological engineering experiment for purifying water in Wulihu Bay of Lake Taihu by using Trapa natans var. bispinosa was constructed. The state variables in water in the physico-biological engineering were ammonium nitrogen (NH_4^+-N); nitrate nitrogen (NO_3^--N); nitrite nitrogen (NO_2^--N); phosphate phosphorus (PO_4^{3-}-P); dissolved oxygen (DO); nitrogen (N) and phosphorus (P) in detritus; biomass density, N and P in phytoplankton and in Trapa natans var. bispinosa, N and P in the substance adsorbed by the membrane of the engineering and the rootstocks of Trapa natans var. bispinosa. The state variables in bottom mud layer were PO_4^{3-}-P in the core water, exchangeable P and N. The external forcing functions were solar radiation, water temperature, NH_4^+-N; NO_3^--N; NO_2^--N; PO_4^{3-}-P; N and P in detritus; DO; phytoplankton concentrations in inflow water and the retention time of the water in physico-biological engineering channel. The main physical, chemical and biological processes considered in the model were: growth of Trapa natans var. bispinosa and phytoplankton; oxidation of NH_4^+-N and NO_2^--N, of detritus break down; N and P sorption by the enclosure cloth of the experimental engineering and by the rootstocks of Trapa natans var. bispinosa in water; reaeration of water; uptake of P, NH_4^+-N, NO_3^--N by phytoplankton and Trapa natans var. bispinosa; mortality of the phytoplankton and Trapa natans var. bispinosa; settling of detritus; and nutrient release from sediment. Comparison of calculated results and observed results showed that the model was constructed reasonably for the experiment. The mechanism of purifying lake water in the experiment engineering was discussed by the use of the model.*

Keywords: *Model, Physico-biological engineering, Water quality, Trapa natans var. bispinosa, Lake Taihu*

1. Introduction

Wulihu bay lies in the northeast part of Taihu Lake, one of the five largest fresh water lakes in China. There was a dense submerged aquatic plant cover in the bay during 1950's. The water of high quality was used as the sources for drinking water plant. But the ecosystem structure has

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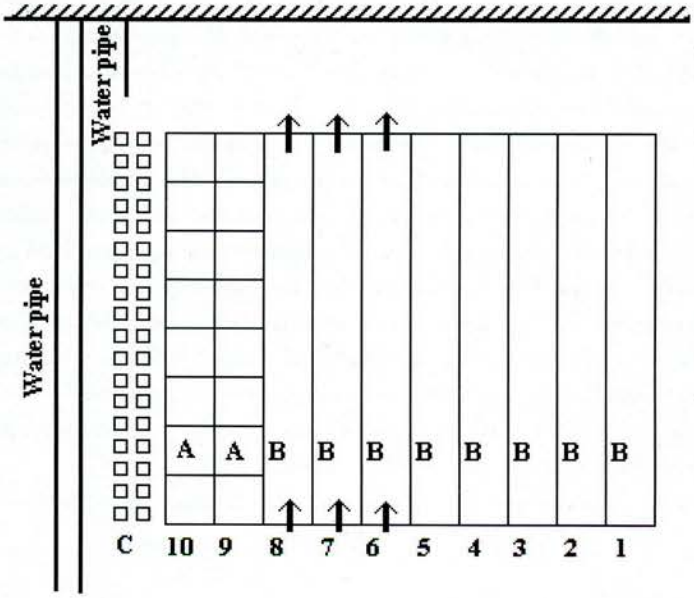
changed rapidly in the last 20 years. Submerged aquatic plants have disappeared. Water bloom often takes place in it (Li, W-CH, 1996). The water transparency was less that 50 cm in 1991~1994. The annual mean concentration of COD in the bay was 57.0 $mg \cdot l^{-1}$ in 1994. The annual mean concentration of ammonium nitrogen (NH_4^+-N) in the water was 0.53 $mg \cdot l^{-1}$ in 1991, 2.75 $mg \cdot l^{-1}$ in 1992, 1.99 $mg \cdot l^{-1}$ in 1993 and 4.12 $mg \cdot l^{-1}$ in 1994. The annual mean concentration of TN was 2.10, 4.69, 6.64, 10.92 $mg \cdot l^{-1}$ in 1991,1992,1993,1994 respectively. The water in it is not the qualified sources of drinking water plant. Some effective measures must be taken to improve the water quality. So a series of physico-biological engineering experiments have been carried out since July 1994 on improving the water quality for the resource of a drinking water plant (Pu, P-M, *et al.*, 1995). A physico-biological engineering experiment for purifying water by using *Trapa natans var. bispinosa* is included in them.

The experimental physico-biological engineering included two parts: physical engineering and the artificial ecosystem. The physical part was soft enclosures, which were made of nontoxic chemical fibre clothe and were constructed in the intake area of the Old Zhongqiao Water Plant in Wulihu Bay. The structure of the physical engineering was shown in Fig.1. There were 10 water channels in it. Each is 5-miter wide and 40-mitre long. Water in Wulihu Bay can only enter each channel at its south end. Different species of aquatic plants were cultured in different channel.



A enclosure for static experiment
B enclosure for dynamic experiment
C area for water plant growth experiment

Fig. 1 Schematic drawing of the experimental engineering

Trapa natans var. bispinosa (*TNVB*) is a kind of leave-floating aquatic vascular plants, with its roots in both sediment and water. It can be easily planted in the shallow lakes. It can grow from April to Oct. in Taihu Lake. The leaf-form roots in water can directly uptake inorganic nutrients from water besides the long fibrous roots in sediment. The roots in water can also adsorb the suspended substance and improve water transparency. It was selected as the water plant to purify the bay water. It was planted in the 8^{th} channel in July. As it grow, the transparency of the water in the channel increased from 60cm to 120cm and were planted in 8th channel (Fig. 1) from Mar. to Oct., 1996. The observed results of the experiment showed that it had a good effect on purifying the water.

This paper is aimed to use numeric simulation method to construct the nitrogen (N) and phosphorus (P) cycling model in the 8th channel in which *TNVB* was planted, to study the water-purifying processes of the plant. The model presented here is based upon previous modelling approaches by S.E. Jogensen (1988), S.E. Jogensen (1994), and Cai Q-H (1995). The model is different from the previous model by being more complex by including the dissolved oxygen (DO) and the process of absorption of suspended substance by the artificial membrane and the surface of the water plant to improve the accurate of the model.

2. Model of nitrogen and phosphorus cycling in the 8th channel

2.1 Conceptual model of the experiment of *TNVB* culturing

Because the nutrient conversions and physical, chemical and biological processes in the 8th channel were too complex, these must be simplified. According to the observed results of the experiment and previous results of L. K. Nielsen's study on mud-water exchange(L. K. Nielsen *et al*, 1974), the conversions and physico-biological and chemical processes in the 8th channel can be summarized as Fig. 2. The biological processes in Fig. 2 are: (1) *TNVB's* and phytoplankton's growths and their uptakes for nutrient ammonium nitrogen (NH_4^+-N), nitrate nitrogen (NO_3^--N) and phosphate phosphorus (PO_4^{3-}-P) from the channel water, (2) *TNVB's* and phytoplankton's mortalities and the nitrogen (N) and phosphorus (P) in them become suspended detritus N and P, (3) Biodegradation of suspended detritus N and P, N and P absorbed by the surface of the enclosure membrane and *TNVB*'s roots, exchangeable P in the bottom and organic Nitrogen in bottom, (4) Oxygen production by phytoplankton photosynthesis. The physical processes in Fig. 2 are: (1) Input and output of NO_3^--N, nitrite nitrogen (NO_2^--N), NH_4^+-N, PO_4^{3-}-P, suspended detritus N and P, dissolved oxygen (DO) and phytoplankton, (2) Settling of detritus to the bottom; (3) absorption of the surface of the enclosure membrane and *TNVB*'s roots, (4) Diffusions of nutrients from the bottom to the channel water; (5) The reaeration of water. The chemical processes in Fig. 2 are: (1) oxidation of NH_4^+-N and NO_2^--N; (2) the chemical processes involved in biological process. In Fig. 2, there were 18 state variables: 3 for the phytoplankton, 3 for *TNVB,* 6 for N, 5 for P, and 1 for DO. The forcing functions are: temperature, solar radiation, the concentrations of NH_4^+-N; NO_3^--N; NO_2^--N; PO_4^{3-}-P; DO; N and P in detritus, and phytoplankton in inflow water.

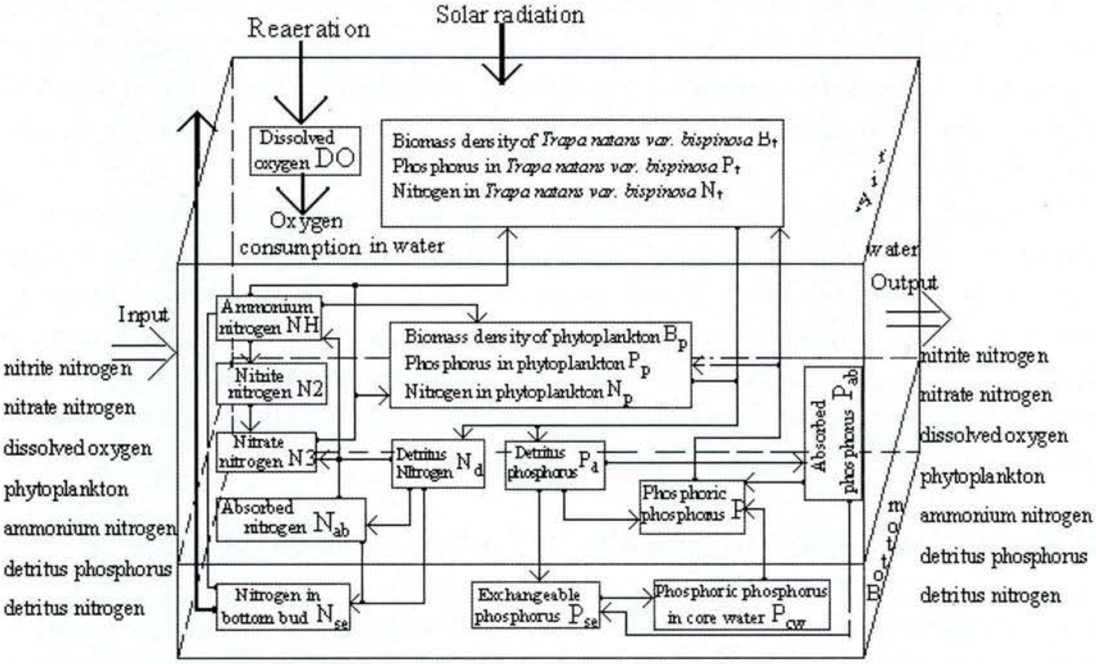


Fig. 2 Conceptual diagram of the model

2.2 Mathematical equations of the model

On the assumption that the biochemical reactions and reaeration followed first-order kinetics and by the use of mass conservation law, the following differential equations (1-18) for state variables of the model can be set up:

$$\begin{aligned}\frac{dNH}{dt} &= Q\cdot NH_i - Q\cdot NH + K\cdot V_{md}\cdot(N_d + N_{ab})\cdot K_{mdt}^{T-20} + e^{0.151(T-20)}\cdot 10^{-5}(32N_{se}+8)\\ &-V_{nho}\cdot NH - NH_{pu} - NH_{tu}\end{aligned} \tag{1}$$

$$\frac{dN3}{dt} = (1-K)\cdot Vmd\cdot(N_d + N_{ab})\cdot K_{mdt}^{T-20} + Q\cdot N3_i - Q\cdot N3 + V_{n2o}\cdot N2 - N3_{pu} - N3_{tu} \tag{2}$$

$$\frac{dN2}{dt} = V_{nho}\cdot NH + Q\cdot N2_i - V_{n2o}\cdot N2 - N2\cdot Q \tag{3}$$

$$\frac{dP}{dt} = Q\cdot P_i - Q\cdot P + V_{md}\cdot K_{mdt}^{T-20}\cdot(P_a + P_{ab}) + V_{mpp}(wei\cdot P_{cw} - P)\cdot {}^{(T+273)}\!\big/_{280} - P_{pu} - P_{tu} \tag{4}$$

$$\frac{dDO}{dt}=\frac{2.26\cdot v\cdot \exp(0.024(T-20))}{R^{2/3}\cdot 3600}\cdot(DO_S-DO)+O_p+Q\cdot DO_i-Q\cdot DO-O_m-O_{ox} \tag{5}$$

$$\frac{dN_d}{dt}=Q\cdot N_{di}-Q\cdot N_d+MR_p\cdot N_p+MR_t\cdot N_t-k\cdot N_d\cdot\frac{N_{a\max}-N_{ab}}{N_{a\max}}-Vmd\cdot K_{mdt}^{T-20}\cdot N_d-0.065N_d \tag{6}$$

$$\frac{dP_d}{dt}=Q\cdot P_{di}-Q\cdot P_d+MR_p\cdot P_p+MR_t\cdot P_t-k\cdot P_d\cdot\frac{P_{a\max}-P_{ab}}{P_{a\max}}-Vmd\cdot K_{mdt}^{T-20}\cdot P_d-0.065P_d \tag{7}$$

$$\frac{dP_{se}}{dt}=\max(0,P_{ab}-P_{a\max})+0.065\cdot P_d-1.4286Pdmk\cdot P_{se}\cdot Kext^{T-20} \tag{8}$$

$$\frac{dP_{cw}}{dt}=1.4286Pdmk\cdot P_{se}\cdot Kext^{T-20}-V_{mpp}\cdot\left(P_{cw}\cdot wei-P\right)\cdot\frac{T+273}{280} \tag{9}$$

$$\frac{dN_{se}}{dt}=\max(0,N_{ab}-N_{a\max})+0.065\cdot N_d-e^{0.151(T-20)}\cdot(32N_{se}+8)\cdot 10^{-5}-10^{-5}\cdot 1.15^{T-20}\cdot N_{se} \tag{10}$$

$$\frac{dB_p}{dt}=GR_p\cdot B_p+Q\cdot B_{pi}-Q\cdot B_p-MR_p\cdot B_p \tag{11}$$

$$\frac{dNp}{dt}=NH_{pu}+N3_{pu}+Q\cdot N_{pi}-Q\cdot N_p-MR_p\cdot N_p \tag{12}$$

$$\frac{dP_p}{dt}=Q\cdot P_{pi}-Q\cdot P_p+P_{pu}-MR_p\cdot P_p \tag{13}$$

$$\frac{dB_t}{dt}=GR_t\cdot B_t-MR_t\cdot B_t \tag{14}$$

$$\frac{dN_t}{dt}=N3_{tu}+NH_{tu}-MR_t\cdot N_t \tag{15}$$

$$\frac{dP_t}{dt}=P_{tu}-MR_t\cdot P_t \tag{16}$$

$$\frac{dN_{ab}}{dt}=k\cdot N_d\cdot\frac{N_{a\max}-N_{ab}}{N_{a\max}}-Vmd\cdot N_{ab}\cdot K_{mdt}^{T-20}-\max(0,N_{ab}-N_{a\max}) \tag{17}$$

$$\frac{dP_{ab}}{dt}=k\cdot P_d\cdot\frac{P_{a\max}-P_{ab}}{P_{a\max}}-Vmd\cdot P_{ab}\cdot K_{mdt}^{T-20}-\max(0,P_{ab}-P_{a\max}) \tag{18}$$

where:

$$NH_{pu}=\frac{VNH_p\cdot NH_{pre}\cdot NH}{NH+KNH_p}\cdot B_p\cdot N_{ppro};\qquad N3_{pu}=VN3_p\cdot N3\cdot\frac{1.0-NH_{pre}}{N3+KN3_p}\cdot B_p\cdot N_{ppro};$$

$$P_{pu}=VP_p\cdot\frac{P_{ppro}\cdot P\cdot B_p}{P+KP_p};\qquad N_{ppro}=\frac{N_{p\max}-N_p/B_p}{N_{p\max}-N_{p\min}};\qquad NH_{tu}=\frac{VNH_t\cdot NH_{pre}\cdot NH}{NH+KNH_t}\cdot B_t\cdot N_{tpro};$$

$$N3_{tu}=VN3_t\cdot N3\cdot\frac{1.0-NH_{pre}}{N3+KN3_t}\cdot B_t\cdot N_{tpro};\qquad P_{tu}=VP_t\cdot\frac{P_{tpro}\cdot P\cdot B_t}{P+KP_t};\qquad N_{tpro}=\frac{N_{t\max}-N_t/B_t}{N_{t\max}-N_{t\min}};$$

$$P_{ppro}=\frac{P_{p\max}-P_p/B_p}{P_{p\max}-P_{p\min}};\qquad P_{tpro}=\frac{P_{t\max}-P_t/B_t}{P_{t\max}-P_{t\min}};\qquad NH_{pre}=\frac{NH}{NH+N3};$$

$$GR_p = G_{\max p} \cdot \min(1 - N_{p\min} \cdot B_p / N_p, 1 - P_{p\min} \cdot B_p / P_p) \cdot e^{-0.007|T-25|} \cdot I_0 \cdot \frac{1 - \exp(-2(1.7/TSP + 0.014B_p)}{2(1.7/TSP + 0.014B_p) \cdot IK} \cdot KF;$$

$$GR_t = G_{\max t} \cdot \min(1 - N_{t\min} \cdot B_t / N_t, 1 - P_{t\min} \cdot B_t / P_t) \cdot 1.05^{-0.024|T-25.8|} \cdot I_0 / 1300 \cdot \pi;$$

$$MR_p = GR_p \cdot B_p / CA_p; \qquad MR_t = GR_t \qquad O_{ox} = 3.429V_{nho} \cdot NH + 1.143V_{n2o} \cdot N2;$$

$$O_m = 17.129(N_d + N_{ab}) \cdot V_{md} \cdot K_{mdt}^{T-20}; \qquad O_p = 1.067GR_p \cdot B_p;$$

$$V_{nho} = K_{nho} \cdot DO / 5.0; \qquad V_{n2o} = K_{n2o} \cdot N2 \cdot \max(0, (DO - 1.5) / 5.5).$$

Definitions of the symbols in above equations have been shown in table 1.

Tab. 1 List of symbols and definitions in above equations

Symbol	Definition	Symbol	Definition
NH	NH_4^+-N concentration in the channel water	N3	NO_3^--N concentration in the channel water
N_{se}	nitrogen in bottom sediment	N2	NO_2^--N concentration in the channel water
B_p	biomass density of phytoplankton	P	PO_4^{3-}-P concentration in the channel water
N_p	nitrogen in phytoplankton	DO	DO concentration in the channel water
P_p	phosphorus in phytoplankton	N_d	concentration of N in detritus in the channel
B_t	biomass density of TNVB	P_d	concentration of P in detritus in the channel
N_t	nitrogen in T. N. V. B .	P_{se}	exchangeable phosphorus in bottom sediment
P_t	phosphorus in TNVB	P_{cw}	phosphorus in core water
P_{ab}	P in the adsorbate on the membrane of engineering and the rootstock of TNVB	N_{ab}	N in the adsorbate on the membrane of engineering and the rootstock of TNVB
N_{di}	concentration of N in detritus in inflow water	P_{di}	concentration of P in detritus in inflow water
DO_i	DO concentration in inflow water	$N3_i$	NO_3^--N concentration in inflow water
NH_i	NH_4^+-N concentration in inflow water	$N2_i$	NO_2^--N concentration in inflow water
P_i	PO_4^{3-}-P concentration in inflow water	B_{pi}	biomass density of phytoplankton in inflow water
P_{pi}	concentration of P in phytoplankton in inflow water	N_{pi}	concentration of N in phytoplankton in inflow water
NH_{pu}	uptake of NH_4^+-N by phytoplankton	$N3_{pu}$	uptake of phytoplankton for NO_3^--N
NH_{tu}	uptake of NH_4^+-N by TNVB	$N3_{tu}$	uptake of TNVB for NO_3^--N
P_{tu}	uptake of PO_4^{3-}-P by TNVB	P_{pu}	uptake of phytoplankton for NO_3^--N
Q	the volume of flow ($m^3 \cdot s^{-1}$)	DO_s	oxygen concentration at saturation
O_{ox}	oxygen consumption of oxidation of NH_4^+-N and NO_2^--N	K_{mdt}	influence constant of temperature on detritus mineralization
T	water temperature in the channel	K_{nho}	oxidation rate of NH_4^+-N when DO=5 $mg \cdot l^{-1}$
K_{n2o}	oxidation rate of NO_2^--N when DO=7.0 $mg \cdot l^{-1}$	υ	average flow ($m \cdot s^{-1}$)
R	water depth in the channel	O_p	oxygen production by phytoplankton growth
O_m	oxygen consumption of detritus and adsorbate	V_{md}	detritus mineralization velocity at 20 ^0C
MR_p	mortality rate of phytoplankton in the channel water	MR_t	mortality rate of TNVB in the channel water
GR_p	growth rate of phytoplankton in the channel water	GR_t	growth rate of TNVB in the channel water
P_{amaax}	maximum value of P_{ab}	Pdmk	P release velocity of anaerobic decomposition at 20 ^0C
k	adsorption rate of the membrane and the rootstock of TNVB	K	ratio of NH_4^+-N to the sum of NH_4^+-N and NO_2^--N produced by mineralization

N_{amax}	maximum value of N_{ab}	$VN3_p$	maximum uptake velocity of phytoplankton for NO_3^--N
Kext	influence constant of temperature on anaerobic decomposition	VNH_p	maximum uptake velocity of phytoplankton for NH_4^+-N
VNH_t	maximum uptake velocity of TNVB for NH_4^+-N	VP_p	maximum uptake velocity of phytoplankton for P
VP_t	maximum uptake velocity of TNVB for P	$VN3_t$	maximum uptake velocity of TNVB for NO_3^--N
V_{mpp}	diffusion coefficient of core water phosphorus	KNH_p	half saturation constant of NH_4^+-N for phytoplankton
$KN3_t$	half saturation constant of NO_3^--N for TNVB	KP_p	half saturation constant of PO_4^{3-}-P for phytoplankton
KNH_t	half saturation constant of NH_4^+-N for TNVB	$KN3_p$	half saturation constant of NO_3^--N for phytoplankton
NH_{pre}	ratio of NH_4^+-N to the sum of NH_4^+-N and NO_3^--N	KP_t	half saturation constant of PO_4^{3-}-P for T. N. V. B
N_{tpro}	normalized value for TNVB intracellular N	N_{ppro}	normalized value for phytoplankton intracellular N
P_{tpro}	normalized value for TNVB intracellular P	P_{ppro}	normalized value for phytoplankton intracellular P
N_{tmax}	Maximum quota of TNVB for N	N_{pmax}	Maximum quota of TNVB for phosphorus
N_{tmin}	Minimum quota of TNVB for N	N_{pmin}	Minimum quota of phytoplankton for P
P_{tmax}	Maximum quota of TNVB for P	P_{pmax}	Maximum quota of phytoplankton for P
CA_p	carrying capacity of phytoplankton	P_{pmin}	Minimum quota of phytoplankton for P
P_{tmin}	Minimum quota of TNVB for P	IK	saturation constant of phytoplankton for light
I_0	solar radiation	G_{maxp}	maximum growth rate of phytoplankton
TSP	water transparency in the channel	G_{maxt}	maximum growth rate of TNVB
KF	cover degree of water by TNVB		

The units of state variables are mg • l^{-1} , and the others are mg • l^{-1} • d^{-1} in table 1.

2.3 Parameters and state variable initial values

The model included more twenty parameters. Some important parameters were obtained from experimental observation, some from numerical simulation, the others from references. The values of the parameters are shown in table 2. The initial values are shown in table 4. For convenience, the state variable B_t, N_t, P_t, N_{se}, P_{se}, P_{cw}, N_{ab}, P_{ab} were converted to the concentration in the whole water column. All the state variables were in unit of mg • l^{-1}.

Tab. 2 Parameters in the model

Symbol	Unit	Value	Source	Symbol	Unit	Value	Source
N_{tmax}	g N/g d.w.	.0.096	umerical simulation	KNH_p	mg/l	).176	S. E. Jorgensen, *et al*, 1991
N_{tmin}	g N/g d.w.	0.0158	'uo, H-SH, *et al.*, 1995	KP_p	mg/l	).010	S. E. Jorgensen, *et al*, 1991
P_{tmax}	g P/g d.w.	0.016	'uo, H-SH, *et al.*, 1995	$KN3_p$	mg/l	).164	S. E. Jorgensen, *et al*, 1991
P_{tmin}	g P/g d.w.	0.00258	umerical simulation	KP_t	mg/l	).010	numerical simulation
N_{pmax}	g N/g d.w.	0.085	endoricchio, G. *et al.*, 1993, 1994	$KN3_t$	mg/l	).150	numerical simulation
N_{pmin}	g N/g d.w.	0.007	endoricchio, G. *et al.*, 1993, 1994	KNH_t	mg/l	0.300	Jin, S-D, 1994
P_{pmax}	g P/g d.w.	0.015	'Cai, Q-H, 1995	VNH_p	l/day	0.3840	. E. Jorgensen, *et al*, 1991
P_{pmin}	g P/g d.w.	0.001	'Cai, Q-H, 1995	$VN3_p$	l/day	0.2400	S. E. Jorgensen, *et al*, 1991
G_{maxp}	1/day	0.11	. E. Jorgensen, *et al*, 1991	VP_p	l/day	0.0025	S. E. Jorgensen, *et al*, 1991
G_{maxt}	1/day	0.11615	bserved	VNH_t	l/day	0.0010	numerical simulation
V_{md}	1/day	0.022	'ai, Q-H, 1995	$VN3_t$	l/day	0.0010	numerical simulation
V_{mpp}	1/day	0.005	umerical simulation	VP_t	l/day	0.0005	numerical simulation
Pdmk	1/day	0.013	'ai, Q-H, 1995	IK	$uE/M^2/s$	.590	from observed results

K		0.55	numerical simulation	K_{mdt}		1.15	Cai, Q-H, 1995
N_{amax}	mg/l		HU, W-P, *et al.*, 1995	Kext		1.13	ai, Q-H, 1995
P_{amax}	mg/l		HU, W-P, *et al.*, 1995	k		0.5	simulation
K_{nho}	1/day	0.03	numerical simulation	K_{n2o}	1/day	0.5	numerical simulation

Tab. 3 Initial value of state variables ($mg \cdot l^{-1}$)

Variable	values	Variable	values	Variable	values
NH	0.32	P_{se}	3.96	N_{ab}	0.0
N3	0.52	P_{cw}	2.2704	P_{ab}	0.275184
N2	0.0022	N_{se}	159.75	P_d	0.05379
P	0.001	B_p	2.163	N_t	40.464
DO	0.47	N_p	0.2163	P_t	3.796
N_d	0.139	P_p	0.02163	B_t	900.0

3. Comparison of simulated results and measured results

Figures 3a, b, c, d, e and f showed the simulated results and measured results of concentration of NH_4^+-N, NO_2^--N, NO_3^--N, DO, phytoplankton and PO_4^{3-}-P in channel water and the inflow water. From Fig. 3, it can be found that simulated values of NH_4^+-N, NO_2^--N, NO_3^--N, DO, phytoplankton and PO_4^{3-}-P were coincided with measured curves in the channel water. This showed the model equations and its parameter values were reasonable. Figure 4 a, b showed values of concentration of TN and TP in the channel water. The tally of simulated results and measured results of TN and TP in Figure 4 further proved the model reasonable.

4. Discussion

Fig. 3 and 4 showed that the concentrations of NH_4^+-N, NO_3^--N, phytoplankton, PO_4^{3-}-P, TN and TP in channel water were lower than those in the inflow water .They suggested the physico-biological engineering could improve lake water quality and lower phytoplankton content. Fig. 3d showed that DO concentration in the channel water was lower than that in the inflow water. It implied that biochemical process in the channel was a consumed oxygen process. This could be seen from Fig. 5. In it the oxygen supply from water reaeration was insufficient to replenishing consumption by the oxidation of NH_4^+-N, NO_2^--N and the mineralization of detritus and adsorbed N. NH_4^+-N could not be oxidized to NO_3^--N completely. The concentration of NO_2^--N in the channel water increased, since oxygen was limiting in the channel. This was also showed by Fig. 3b. These results imply that other steps must be taken to increase the DO concentration and decrease NO_2^--N concentration in the channel water.

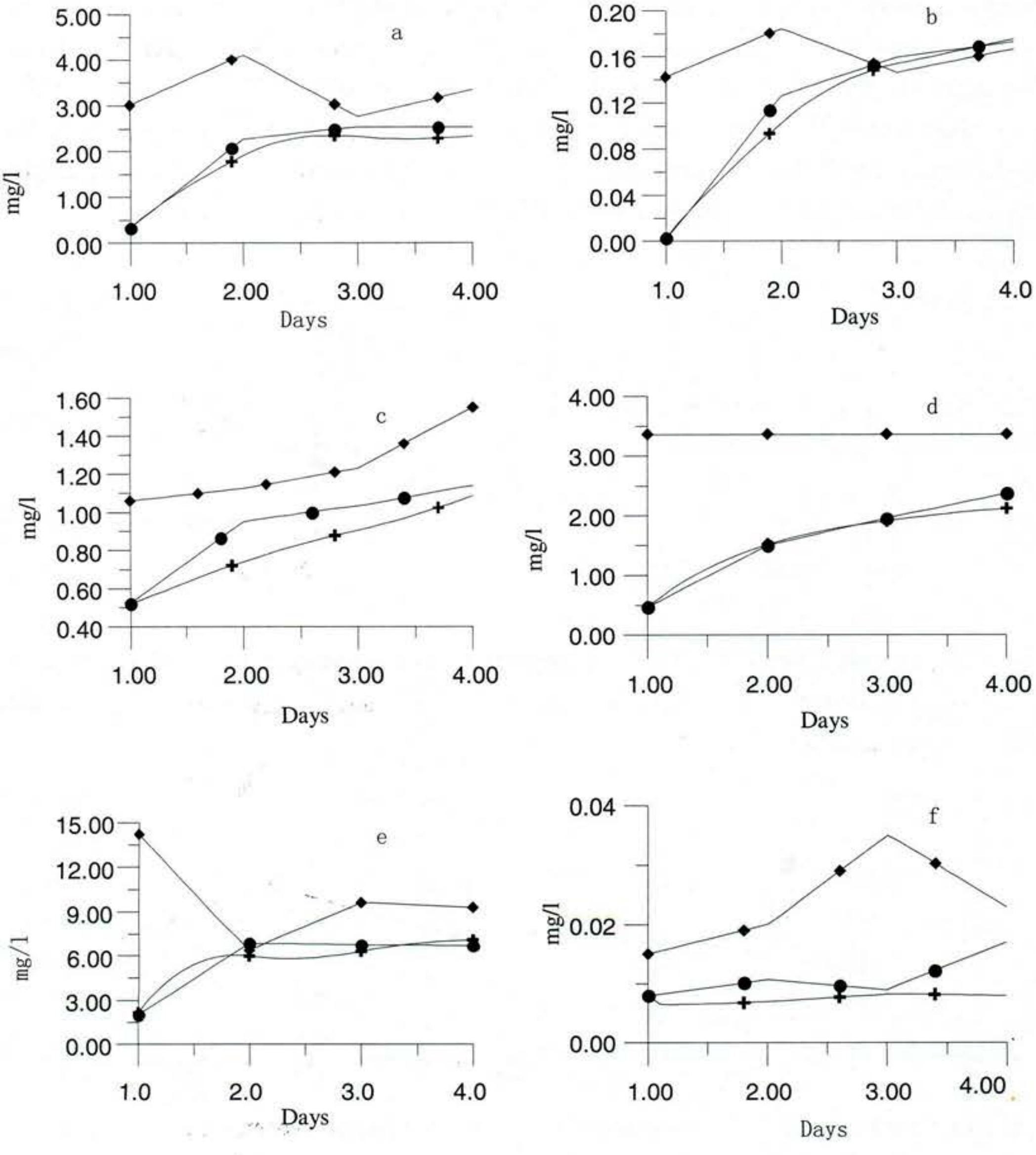


Fig. 3 Water parameter procedure curves during the experimental period. a- NH_4^+-N, b- NO_2^--N, c- NO_3^--N, d- DO, e- phytoplankton biomass density, f- PO_4^{3-}P, +—calculated concentration in the channel water, —observed concentration in the channel water ◆—observed concentration in inflow water

Fig. 6 showed NH_4^+-N flow during the experimental period. The uptake of NH_4^+-N by *TNVB* was 0.113 - 0.402 $mg \cdot l^{-1} \cdot d^{-1}$, which was higher than the oxidation of NH_4^+-N (0.001~0.036 $mg \cdot l^{-1} \cdot d^{-1}$) and the release from bottom sediment (0.016~0.019 $mg \cdot l^{-1} \cdot d^{-1}$), and about 20% of the amount of NH_4^+-N outflow. Fig. 7 showed the N flow in channel water obtained from the model. The rate of N settling to the bottom sediment was higher than the rate of plant uptake by *TNVB*. However, this plant N uptake rate was greater than the physico-adsorption effect of N by the membrane of the experimental engineering and rootstock of *TNVB*. It also showed that N-flow from the bottom to the channel water was smaller than the N-flow from the water to the bottom. This described that N-nutrient was deposited on the bottom surface. Fig. 8 was the detritus N source flow during the experimental period. It described that the detritus N mainly came from dead *TNVB*. As to P flow, the model described that the diffusion of P_{cw} was relatively stable, it was smaller than the uptake of P by *TNVB* and detritus P settling to bottom surface.

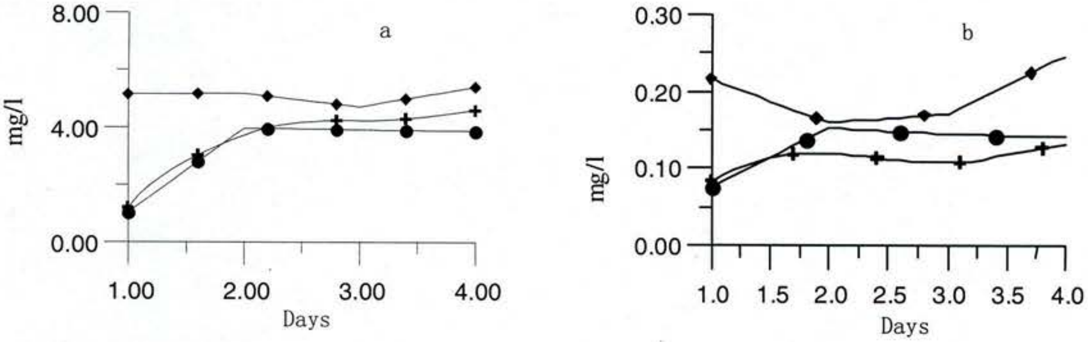
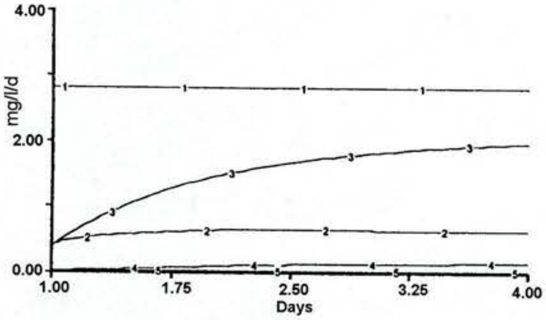


Fig. 4 TN, TP concentration curves from the model and measurement. a-TN, b-TP. +— observed concentration in the channel water ●— calculated concentration in the channel water, ◆—observed concentration in inflow water



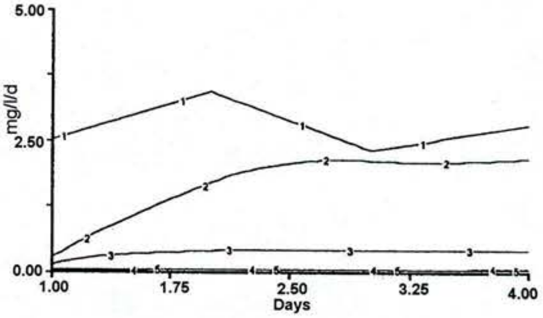


Fig. 5 Oxygen input and output change curves in the channel water. 1-oxygen input due to the water inflow, 2-oxygen consumption due to the mineralization taken place in water, 3- oxygen output due to the water outflow, 4-oxygen consumption due to the oxidation of NH_4^+-N and NO_2^--N, 5-oxygen input due to water surface reaeration

Fig. 6 The flow curves related to the NH_4^+-N concentration in the channel water. 1-NH_4^+-N input due to the water inflow, 2- NH_4^+-N output due to the water outflow, 3-due to the uptake of T. N. V. B. For NH_4^+-N, 4-NH_4^+-N output due to oxidation, 5-NH_4^+-N inflow due to the NH_4^+-N release from bottom.

The model also described that the uptake of P by *TNVB* was greater than the uptake of P by phytoplankton. Therefore, the model revealed that the main mechanisms of purifying water in the experimental engineering were that *TNVB* limited the growth of phytoplankton and its uptake for nutrient from channel water. Most of the NH_4^+-N and NO_3^--N, PO_4^{3-}-P in water was taken up by *TNVB* and assimilated into its biomass. As a result of *TNVB* mortality, detritus N and P settled to bottom and was deposited on the bottom.

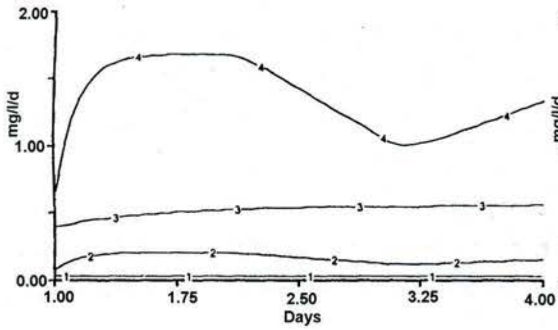


Fig. 7 The N flow curves in the channel water. 1- N release from the bottom, 2- N flow from detritus to adsorption N, 3- N flow from water to T,N.V.B, 4- N flow from water to the bottom.

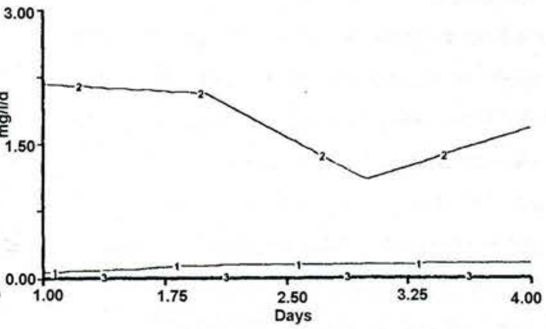


Fig. 8 The change curves of the source of detritus N in the channel water. 1-detritus N input from dead phytoplankton, 2-detritus N input from dead T. N. V. B.. 3- detritus iuput due to the water inflow.

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