Advance Journal of Food Science and Technology 5(2): 110-114, 2013
DOI:10.19026/ajfst.5.3228
ISSN: 2042-4868; e-ISSN: 2042-4876

Submitted: August 31, 2012 Accepted: October 03, 2012 Published: February 15, 2013

Research Article

Paddy Surface Flow used to Improve Fishpond Water

[1]Yuan Zhou, [1,2]Jian-qiang Zhu, [1]Qi-xia Wu and [1]Xiu-juan Wang and [3]Gu Li
[1]Agricultural Department of Yangtze University,
[2]Engineering Research Center of Wetland Agriculture in the Middle Reaches of the Yangtze River, Ministry of Education, Jinzhou, 434025, China
[3]Yangtze River Fisheries Research Institute, Chinese Academy of Fishery Science, Wuhan, 430223, China

Abstract: In improving fishpond water, constructed wetlands and multi-function ecological system generally are used, these methods improve fishpond water quality by surface flow and need a high cost in facilities' construction and operation so that affect them to be widely extended in the production practice. Aiming at the solution, an experimental study was made that paddy field was used for purifying fishpond water, the results showed that: 1) the improvement of aquaculture water by surface flow in the paddy field is related with growth period, effects in water quality improvement are best in the heading stage of rice, weakest in the yellow ripening stage; 2) the removal rate of some nutrients has a close relationship with their initial concentration in irrigated water from fishpond, the distance and velocity of the water flowing on paddy surface. The most significant efficiency on removal rate is flow path. So when the paddy field surface flow is used for water purification, the flow path should be considered firstly; 3) the paddy field surface flow has an oxygen-enriched function in certain amount of the aquaculture water, which is beneficial for aquaculture.

Keywords: Fertile water from aquaculture, paddy field, surface flow, water quality improve, water recycle

INTRODUCTION

Because of the uneven rainfall distribution in temporally and spatially, dry year and seasonal drought may appear in center-east and southwest of China where generally are damp, rainy and rich in water resources (Zhu, 2011). In addition, surface water resource available for aquaculture become more and scarcer due to surface water pollution and on-going water environment degradation. Therefore, people have to extract the groundwater to supplement fishpond in some cases. At present, traditionally intensive aquaculture in fishpond is characterized by high-density, semi-enclosed feeding and lentic environment, which brings a challenge not only to water environment but also to aquaculture itself (Peng *et al*., 2010; Ge *et al*., 2010). Based on sustainable freshwater aquaculture, some researches have been done that ecological water treatment facilities are applied to fishpond aquaculture and some key technologies have been developed in a combination of fishery and agriculture so as to match the mode of traditional pond aquaculture pattern (Wu *et al*., 2011; Zhou *et al*., 2011a, 2011b; Zhu *et al*., 2011). Now health ecological aquaculture has become a trend in fishery production at home and abroad.

In the view of resources-saving, such substances in fishpond may be reused because its available for plants, such as piscine excrements, biological carcass, remanent bait and other organic excrements etc., are good organic fertilizer and essential for crops. So it is good to establish a compounded system consisting of aquaculture pond and paddy field, in the system, water cycle is a link between the aquaculture pond and paddy field and by which fish farming and crop farming are tightly put together that embodies the idea of water-saving, water environment protection. The system is beneficial to the reuse of pond water and the nutrients contained in it. At the same time, such system can save fertilizer dosage in agricultural production, reduce the fish disease and improve the comprehensive ecological efficiency of fishpond.

The purpose of this research is to use aquaculture water from fishpond to irrigate paddy field under different fertilization treatments and various velocities of surface flow in paddy fields and study the paddy fields' effect on improving water quality so as to provide theoretical basis for good combination of fishpond aquaculture and rice production.

MATERIALS AND METHODS

Test site is located in freshwater pond eco-aquaculture base in Shashi, Hubei province which was attached to the Yangtze River Fisheries Research

Corresponding Author: Jian-qiang Zhu, Agricultural Department of Yangtze University, Jinzhou, 434025, China

Table 1: Fertilization treatment in experimental plots

Experimental plots	1	2	3	4
Fertilizer dosage	20% F_0	40% F_0	60% F_0	80% F_0

Institute. Experimental field nearby fishpond was divided into 4 plots with same size, each plot was equipped with independent irrigation and drainage system so that controlled tests in irrigation and drainage could be carried out. By controlling water flow at the imports and exports in the plots and designing different fertilization level, some relevant experiments were done from May to Oct in 2012, so as to understand surface flow in paddy field to purify fishpond water and an effect of fertilizer-saving when fishpond water is used to irrigate paddy field.

In order to arrange different fertilization treatments, 4 experimental plots were set up and separated by waterproof bank (20 cm wide and 30 cm high) which were covered with plastic film. During whole growing period of rice, pond aquaculture water was irrigated to the plots. Each plot with an area of 60 m^2 was arranged a kind of experiment treatment in fertilization (Table 1). In Table 1, F_0 is a conventional fertilizer dosage used for hybrid mid-season rice that's 150 kg/hm^2 for pure N, 120 kg/hm^2 for K_2O and 75 kg/hm^2 for P_2O_5. For each fertilization treatments, they have a same kind of basic fertilizer and tillering stage dressing that were added into the field separately on June 8 and June 17, 2011.

Rice variety for experiment is Y Liang-you 11, its plants were transplanted to trial plots on 8 June 2011, with 25 cm spacing between plants and 30 cm spacing between rows. During rice growth, 20 mg/L of Chlorantraniliprole was used to spray for prevention pest. The harvesting was on 24 Sep, 2011.

The surface flow in each plot was managed according to water balance between irrigation and drainage. The test was conducted in different surface flow at the different stages during rice irrigation. Sampling at the export in each plot and on the field surface every 10 m, these samples were used for analyzing the water quality index of NH_3-H, NO_3^--N, TN, TP, while DO was determined by the portable instrument. Sampling and analytical methods were reference (MEP, 2002). The specific methods are Nessler's reagent spectrophoto-metric method for NH_3-N, spectrophotometry of phenol disulfonic acid for NO_3^-- N, K_2 S_2 O_8 -spectrophoto-metric-ultraviolet spectrophotometry for TN, molybdenum-antimony anti-spectrophotometry for TP.

RESULTS AND DISCUSSION

Analysis of the purification effects of paddy fields surface flow on pond aquaculture water: Fishpond water treated by paddy surface flow, it may be purified. But the purification effects are not quite same in different flowrate and different period of rice, as shown in Table 2, 3 and 4.

Table 2: Removal efficiency of several substances under different surface flow at booting stage

				R_m/%		
Index	Plots	Q/(m^3/h)	C_0/(mg/L)	10 m	20 m	30 m
NH_3-N	1	6.2	1.092	2.55	8.860	15.43
		3.6	1.084	3.06	8.440	17.66
	2	6.2	1.092	3.13	10.33	13.63
		3.6	1.084	5.41	12.16	14.19
	3	6.2	1.092	3.40	9.030	17.21
		3.6	1.084	3.94	10.26	15.49
	4	6.2	1.092	4.55	9.480	18.86
		3.6	1.084	3.88	10.49	18.47
NO_3^--N	1	6.2	0.756	1.34	6.860	12.68
		3.6	0.723	1.99	7.980	13.93
	2	6.2	0.756	3.97	6.600	13.13
		3.6	0.723	0.00	6.960	14.88
	3	6.2	0.756	3.61	8.790	14.95
		3.6	0.723	3.97	8.950	16.94
	4	6.2	0.756	2.71	8.150	15.96
		3.6	0.723	2.96	7.950	16.93
TN	1	6.2	1.857	3.30	12.19	23.59
		3.6	1.957	4.85	11.33	24.20
	2	6.2	1.857	3.46	10.43	23.65
		3.6	1.957	4.91	11.26	23.12
	3	6.2	1.857	6.34	11.92	24.75
		3.6	1.957	4.37	12.29	25.25
	4	6.2	1.857	4.78	13.74	25.41
		3.6	1.957	4.76	15.08	26.13
TP	1	6.2	0.306	0.00	5.250	9.710
		3.6	0.179	0.11	5.070	11.07
	2	6.2	0.306	1.02	6.040	10.10
		3.6	0.179	1.71	5.730	12.15
	3	6.2	0.306	1.41	7.230	12.25
		3.6	0.179	1.49	8.770	12.36
	4	6.2	0.306	1.21	8.040	11.68
		3.6	0.179	1.81	7.970	13.01

R_m is a removal rate of a certain substance, %

As can be seen from these results:

- Flow rate of water flow in paddy field affects water purification effect, generally a small flow rate (3.5 m^3/h) has an obvious effect of water purification in contrast to that produced by larger flow rate (5.5 m^3/h). Because the aquiculture water strands in the paddy fields was too short, the nutrients contained in it can't be fully absorbed by rice plants and fixed by paddy soil.
- Fertilization level has a little effect on water purification when difference of flow rate is smaller between different surface flows (i.e., 6.2 and 3.6 m^3/h, or 5.5 and 3.5 m^3/h) and a significant influence may produce when difference of flow rate is larger (i.e., 5.5 and 1.4 m^3/h), the smaller of the flow rate is and the significant of influence from fertilization level is.
- Paddy surface flow produces a different influence on water purification in different stages of rice. The best effect is in the heading period and the weakest effect is in the yellow ripe stage. The reason is that

Table 3: Removal efficiency of several substances under different surface flow conditions at heading stage

				R_m/%		
Index	Plot	$Q/(m^3/h)$	$C_0/(mg/L)$	10 m	20 m	30 m
NH_3-N	1	5.5	1.165	5.34	6.810	10.59
		3.5	1.141	0.91	5.010	6.920
		1.4	1.266	3.15	12.25	23.01
	2	5.5	1.165	6.32	7.700	14.85
		3.5	1.141	1.87	4.160	10.02
		1.4	1.266	3.35	10.28	19.91
	3	5.5	1.165	5.49	7.510	16.79
		3.5	1.141	5.03	9.020	17.49
		1.4	1.266	7.30	12.62	26.23
	4	5.5	1.165	5.52	7.640	13.82
		3.5	1.141	3.54	16.49	36.73
		1.4	1.266	5.85	22.94	29.79
NO_3^--N	1	5.5	0.548	1.03	7.250	9.110
		3.5	0.758	2.55	5.950	11.27
		1.4	0.918	4.05	11.03	18.14
	2	5.5	0.548	4.89	8.770	15.73
		3.5	0.758	2.71	3.300	14.55
		1.4	0.918	3.31	8.400	17.77
	3	5.5	0.548	2.29	8.890	16.93
		3.5	0.758	2.48	7.250	12.97
		1.4	0.918	4.05	15.15	22.99
	4	5.5	0.548	1.83	5.350	12.88
		3.5	0.758	5.53	8.140	14.02
		1.4	0.918	8.21	15.19	29.30
TN	1	5.5	1.797	6.49	9.950	13.75
		3.5	1.928	8.94	9.220	17.38
		1.4	2.294	11.27	15.12	20.83
	2	5.5	1.797	7.53	10.80	19.09
		3.5	1.928	8.40	11.14	15.05
		1.4	2.294	10.85	12.10	25.75
	3	5.5	1.797	3.23	8.220	13.68
		3.5	1.928	5.38	9.090	27.32
		1.4	2.294	8.47	12.68	37.94
	4	5.5	1.797	7.83	8.320	15.10
		3.5	1.928	7.66	10.51	15.29
		1.4	2.294	11.17	16.13	31.68
TP	1	5.5	0.209	0.33	5.770	10.58
		3.5	0.169	2.07	7.030	16.75
		1.4	0.186	5.81	9.800	21.79
	2	5.5	0.209	1.59	7.170	11.41
		3.5	0.169	1.84	9.920	10.79
		1.4	0.186	3.83	9.820	12.80
	3	5.5	0.209	3.79	6.530	9.550
		3.5	0.169	1.19	8.990	11.90
		1.4	0.186	2.81	15.80	15.80
	4	5.5	0.209	4.05	9.960	11.04
		3.5	0.169	3.03	9.370	11.14
		1.4	0.186	5.82	12.81	15.80

the plants are taller in the heading stage and its organs almost have grown fully so that rice plants have a strong ability to absorb the nutrients in aquaculture water. But in yellow ripe stage, rice plants have a small demand of nutrient due to its organ function decreases gradually.

Analysis of the purification effects of paddy fields surface flow on pond aquaculture water: Regression analysis of experimental data was done by software package DPS7.05, the results (Table 5) showed that, the removal rate of nutrient substances contained in fishpond water by paddy surface flow have a significant or highly significant correlation with three factors that are nutrient content in irrigation water (C_0, namely initial concentration), flow path (D_f) and flowrate of surface flow on paddy field surface (Q). Such correlation can be expressed by a ternary model shown as in Eq. (1) and Table 5 gave some parameters with respect to Eq. (1):

$$R_m = a \cdot C_0 + b \cdot D_f + c \cdot Q + C \tag{1}$$

where,

R_m = The removal rate of nutrient contained in fishpond water under the condition of paddy surface flow, here the nutrients mainly are NH_3-N, NO_3^--N, TN and TP, with unit of %

C_0 = The nutrient content in the irrigation water (from fishpond), it may be one of the NH_3-N, NO_3^--N, TN and TP, with unit of mg/L

D_f = The flow path that the irrigation water flow through on the paddy surface, with unit of m

Q = The flow rate of irrigation and drainage, with unit of m^3/h; a, b, c are regression coefficients and C is a constant, which is different for different ingredient

According to Table 5, Eq. (1) may be understood ulteriorly that the removal rates of some nutrients in fishpond water is proportional to the initial Concentration (C_0) and flow path (D_f) and inversely proportional to the flow rate of surface flow (Q). In addition, in light of general statistical knowledge, the influence of different independent variables (e.g., C_0, D_f and Q) on dependent variable (R_m) may be obtained by comparing the standardized coefficient of different variable. As can be seen from Table 5, C_0, D_f and Q have a different influence on nutrition removal. Three factors (C_0, D_f and Q) are given in order from big to small according to their impact on removal rate of some nutrients. For an impact on ammonia nitrogen (NH_3-N) and Total Phosphorus (TP), the corresponding order is D_f, Q, C_0; for an influence on nitrate nitrogen (NO_3^--N) and Total Nitrogen (TN), the order is D_f, C_0 and Q.

For a certain aquaculture, the concentration of certain substance have a small difference, in this case a distance (flow path) that the fertile water from fishpond passes through paddy surface may play an important role in water purification and has a high removal rate for some nutrient substances. That is, paddy surface flow may produce a good effect in fishpond water purification through selecting a suitable flow path.

In addition, flow rate of surface flow within the paddy field also affect on removal rate for some nutrient substance, here two methods can be used: one is using smaller flow rate to increase the removal rate in single water cycle, but the water exchange between fishpond and paddy field is small and in this case the water quantity necessary to healthy aquiculture must be considered; another method is to increase times of

Table 4: Removal efficiency of several substances under different surface flow at yellow maturity period of rice

		Plot 1			Plot 2			Plot 3			Plot 4		
dex	C_0 mg/L	10	20	30	10	20	30	10	20	30	10	20	30
NH_3-N	1.528	1.04	1.23	1.37	0.97	1.23	1.36	1.08	1.32	1.36	1.01	1.26	1.39
NO_3^--N	0.842	0.70	0.91	1.02	0.66	0.90	1.06	0.67	0.89	1.08	0.71	0.91	1.07
TN	2.690	1.53	1.72	1.89	1.45	1.69	1.91	1.53	1.71	1.92	1.52	1.75	1.89
TP	0.073	0.78	1.03	1.14	0.81	1.04	1.16	0.81	1.02	1.14	0.79	1.03	1.15

C_0 is initial concentration; The data in the table were gained when flow rate of paddy surface flow is 1.1 m^3/h

Table 5: The relevant parameters in Eq. (1)

Ingredient	Factor	Coefficient	Standardized coefficients	Coefficient of multiple correlation	F	Sig.
NH_3-N	C	-8.8780		0.876	12.056	0.001
	C_0	9.8120	0.066			
	D_f	0.9430	0.795			
	Q	-1.8310	-0.319			
NO_3^--N	C	-13.776		0.938	26.871	0.000
	C_0	19.100	0.322			
	D_f	0.6790	0.794			
	Q	-0.8900	-0.215			
TN	C	-6.0760		0.907	16.995	0.000
	C_0	5.8500	0.119			
	D_f	0.7150	0.887			
	Q	-0.3240	-0.083			
TP	C	-1.2150		0.950	33.652	0.000
	C_0	18.449	0.155			
	D_f	0.6160	0.845			
	Q	-1.8710	-0.531			

Table 6: Field variation along the surface water DO determination results

Plot	Index	Water inlet	Apart from the inlet 10 m	Apart from the inlet 20 m	Water outlet
1	DO (mg/L)	5.02	5.900	5.960	6.960
	DO increase (%)	0.00	17.53	18.73	38.65
2	DO (mg/L)	5.02	5.650	6.050	6.280
	DO increase (%)	0.00	12.55	20.52	25.10
3	DO (mg/L)	5.02	6.050	7.350	7.690
	DO increase (%)	0.00	20.52	26.49	33.27
4	DO (mg/L)	5.02	6.190	6.080	7.170
	DO increase (%)	0.00	23.31	21.12	42.83

The results were gained when flow rate of the paddy surface flow is 3.6 m^3/h

water circulation between fishpond and paddy field, in this situation adoptable flow rate of surface flow may be larger and the correspondingly energy consumption must be considered. Obviously, it may be a good way for aquaculture and water environment to adopt suitable flow rate of surface flow and flow path in the field.

Analysis of oxygen-enriched function: Paddy field can purify pond aquaculture water and also can increase Dissolved Oxygen (DO). Table 6 gives results of DO varying with the distance of the water flowing through paddy field (D_f).

Results in Table 6 showed that DO enhance with the increase of D_f as aquiculture water treated by paddy surface flow, which can be explained by three main reasons: first is that photosynthesis of rice plants produces a large amount of oxygen and forms a local mirco-environment of oxygen enrichment between the water surface and the top of rice plants which leads to DO increase accordingly. Secondly rice plant has a function to convey oxygen in atmosphere to rice roots by its catheter, which increases the oxygen content in paddy soil and rice root zone, thus, after fishpond water is irrigated to paddy field its DO increases. Finally, the process of the fertile water from fishpond flowing on paddy surface creates an oxygen enrichment environment due to its enough aeration.

CONCLUSION

- The purification effect of the paddy surface flow on fertile water from fishpond is different in the different growth stages of rice. The effect obtained is best in the heading period, weakest in the yellow ripe stage. In addition, the removal efficiency of different nutrient is not equal as paddy surface flow is used to improve fishpond water, the removal efficiency for various forms of nitrogen are relatively higher than that for phosphorus.
- When paddy surface flow is used to improvement fishpond water, the removal rate of nutrient substance in it has a close relationship with initial concentration of the nutrient in irrigating water (C_0), the distance of fishpond water flowing

through paddy surface (i.e., flow path, D_f) and flowrate of the surface flow (Q), in which, the influence of D_f on removal rate is most significant. Therefore, when paddy surface flow is used for purifying fishpond water, it is important to select suitable flow path.

- Using paddy surface flow for water purification, it is needed to adopt suitable flow rate and flow path. So that can not only increase water quantity that circulate between fishpond and paddy field but also DO and removal rate of some nutrient substances.
- The removal rate of N and P is low in paddy field with a small length, which can be solved by increasing distance that fishpond water flowing through paddy surface (namely flow path, D_f), the method is to set up U-shaped watercourse within paddy field to extend flow path, so that can not only increase the removal rate of N and P, but also further enhance dissolved oxygen.
- Fishpond water treated by paddy surface flow can increase its DO, which is beneficial for aquaculture. But the mechanisms of oxygen enrichment is not very clear at present, therefore, the relevant research should be further deepened.
- Compared with constructed wetlands in improving fishpond water, the most prominent characteristics by surface flow in paddy field is low cost, increase of dissolved oxygen and convenient for extension in agricultural practice because it is benefic to farmers that a good combination of fish farming and crop farming may get water-saving, fertilizer-saving and water quality improvement for freshwater aquaculture in fishpond.

ACKNOWLEDGMENT

The accomplishment of this study got the support from the national project of major freshwater fish industry technology system (CARS-46-18), Hubei provincial project in the public interest. Meanwhile thanks to assistance from Dr. Ling Tao, Shi-yang Zhang and Xiao-li Li etc., during the research.

REFERENCES

Ge, C., H. Yu and W. Tang, 2010. Research on quality variation and rehabilitation of intensive pond aquaculture wastewater. J. Wuhan Univ. Technol., 32(5): 124-128.

MEP (Ministry of Environmental Protection of the People's Republic of China), 2002. Water and Wastewater Monitoring and Analysis Methods. 4th Edn., China Environmental Science Press, Beijing, (In Chinese).

Peng, G., W. Liu, J. Tong, W. Yan, Q. Lu and J. Tang, 2010. Ecological aquaculture analysis in a recirculating water pond. Fisheries Sci., 29(11): 643-647.

Wu, Q., J. Zhu, Y. Zhou and G. Li, 2011. Purification effect of paddy field on fertile water from fishpond under different water management modes. Proceedings of 2011 International Symposium on Water Resource and Environmental Protection, Yangtze River, Yangtze University, Jingzhou, China, 4: 2687-2691.

Zhou, Y., J. Zhu and G. Li, 2011a. The nutrients in the fertile water from fishpond assimilated and utilized by paddy field. Proceedings of 2011 International Symposium on Water Resource and Environmental Protection, Yangtze River, Yangtze University, Jingzhou, China, 4: 2695-2698.

Zhou, Y., J. Zhu and G. Li, 2011b. Study on purification of aquaculture wastewater from fishpond with compound eco-ditch. Proceedings of 2011 International Conference on Ecological Protection of Lakes-Watershed and Application of 3S Technology Workshop (EPLWW3S 2011), Kowloom: International Industrial Electronic Center, pp: 211-216.

Zhu, J., 2011. Report on Water Reuse Technology within a Composite Ecosystem of Fishing and Farming. Yangtze University, Jing Zhou, HuBei.

Zhu, J., K. He, X. Tian, *et al*., 2011. Drought-prevention, drought-resistance and rescue under emergency for agriculture in plain-lake region in hubei province. J. Irrig. Drain., 30(5): 1-6.