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Research Article

Wastewater from a trout farm for rice cultivation: case study in Chiang Mai Province, Thailand

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Abstract

The Experimental Fishery Station of the Royal Project Foundation established at a Karen village, Mae Klang Luang, on Inthanon Mountain has been cultivating rainbow trout with the objective of providing alternative employment and for providing an additional protein food source for the Karen people. The trout farm generates wastewater containing nutrients, such as ammonia-nitrogen and phosphorus. Currently, wastewater is released from the farm to three different sinks, i.e., upland rice field, experimental rice field with crayfish farm and natural stream nearby the village. The objective of this research is to determine quality and quantity of wastewater from the rainbow trout farm as a nutrient source for the upland rice cultivation and to offer an appropriate wastewater management option for the farm. Further, an additional advantage of wastewater use for upland rice (i.e., Med-Luang variety) cultivation is the reduction of nutrients in wastewater before discharging to natural streams. The information was collected as both primary and secondary data. Total nitrogen (ammonia-nitrogen and nitrite) and ortho-phosphate were analyzed. The wastewater contained total nitrogen of 0.21± 0.08 mg/L and orthophosphate of 0.17 mg/L. Wastewater flow rate was approximately 1,670 L/min. Eighteen households—two households growing rice using trout farm wastewater and the other 16 households growing rice using water from other sources—were interviewed. Data on rice yield and rice appearance were collected. The qualitative comparison showed that insignificant differences in rice yields and rice appearance were observed. Rice fields that used wastewater from the trout farm found a higher number of rice tillering. The reason may be due to the nutrients from the trout wastewater or other addition of organic compost and chemicals.

Keywords: nitrogen, *Oncorhynchus mykiss*, rainbow trout, recycling, Karen.

Introduction

The Royal Project Foundation has established their second rainbow trout farm at Mae Klang Luang village on Inthanon Mountain in the north of Thailand. The Fishery Station has been cultivating rainbow trout with an aim to be an alternative form of employment and as a protein food source for the Karen people [1, 2]. The Karen village of Mae Klang Luang, located in Jom Thong District, Chiang Mai Province and has a population of approximately 60-80 households [3]. The villagers currently cultivate a variety of crops, such as rice, coffee, temperate vegetables and fruit.

The rainbow trout farm requires a large amount of water through its flow-through raceway ponds at approximately 250 L/min [4]. The trout farm generates wastewater containing nutrients, such as ammonia-nitrogen and phosphorus. Currently, wastewater is released from the farm to three different sinks, i.e., upland rice field, experimental rice field with crayfish farm and natural stream nearby the village. Two households utilize the benefits of nutrients in the wastewater from the rainbow trout farm for rice growing purposes. Further, this use of wastewater for rice cultivation may finally result in an environmental friendly trout farm with no nutrient release to the environment. Therefore, this research investigated the possibility of the utilization of trout farm wastewater for upland rice cultivation and its potential benefits.

Research Methodology

Water quality analysis

Wastewater samples (using grab sampling method in the wastewater pond) from the trout farm were collected to determine pH, temperature, dissolved oxygen (DO), ammonium-nitrogen, nitrite-nitrogen and ortho-phosphorus. Samples were taken every 2 hours between 8.00 am and 4.00 pm for 3 days in each month of December 2008 to February 2009. Ammonia-nitrogen concentrations were determined by the low-level Indophenol method [5]. Nitrite nitrogen concentrations were determined by the Diazotization method [5]. Ortho-phosporus concentrations were determined by the ascorbic acid or Murphy-Riley method [5]. The pH, temperature, dissolved oxygen (DO) were measured on-site.

Wastewater flow rate analysis

The water flow rate (WR) in irrigation channels and trout raceway ponds was similar to the wastewater flow rate, since the farm uses a flow-through system. Samples were taken every 2 hours between 8.00 am - 4.00 pm for a period of 3 days in each month, for 3 months during December 2008 and February 2009.

Survey and interviews

Eighteen households—two growing rice using trout farm wastewater and the other 16 households growing rice using water from other sources—were interviewed. The field size, annual rice yield, rice appearance, water requirement, price and amount of agro-chemicals used were collected.

Results and Discussion

Wastewater quantity and quality

Wastewater from the trout farm was measured at the cesspool. Figure 1 illustrates wastewater flow rates over time for the three sampling periods. The wastewater flow rates from December 2008 to February 2009 were 1,607.4±122.9, 1,690.0±45.0 and 2,204.2±42.8 L/min, respectively. The average wastewater flow rate for the three months was 1,834.2±323.2 L/min. Based upon the calculation, the specific flow rate was approximately 1.6-2.4 L/min/m^2. The proper specific flow rate as recommended by Stephen [6] was at least 2.5 L/min/m^2 and fish density at 4-5 kg/m^2.

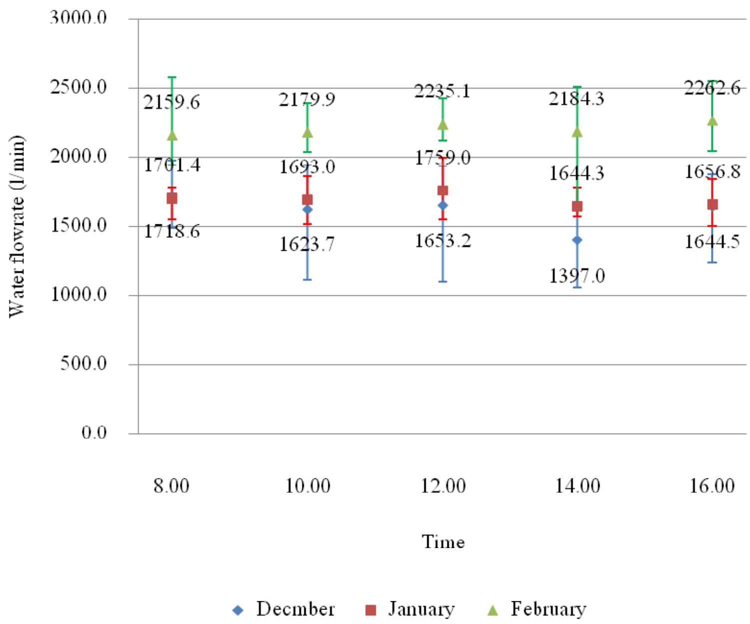

Figure 1. Wastewater flow rate during December 2008 to February 2009.

The wastewater flow rate increased due to the water flow adjustment by the farm personnel to facilitate the increase in fish size and temperature. Average fish weight was 180 grams in December 2008 and 230 grams in February 2009. Further, a higher throughput of water was needed at a higher temperature as average temperatures in December 2008, January 2009 and February 2009 was 16, 15, and 26^{o}C, respectively.

Figures 2 and 3 present average ammonia nitrogen and ortho-phosphorus concentrations during the three month period.

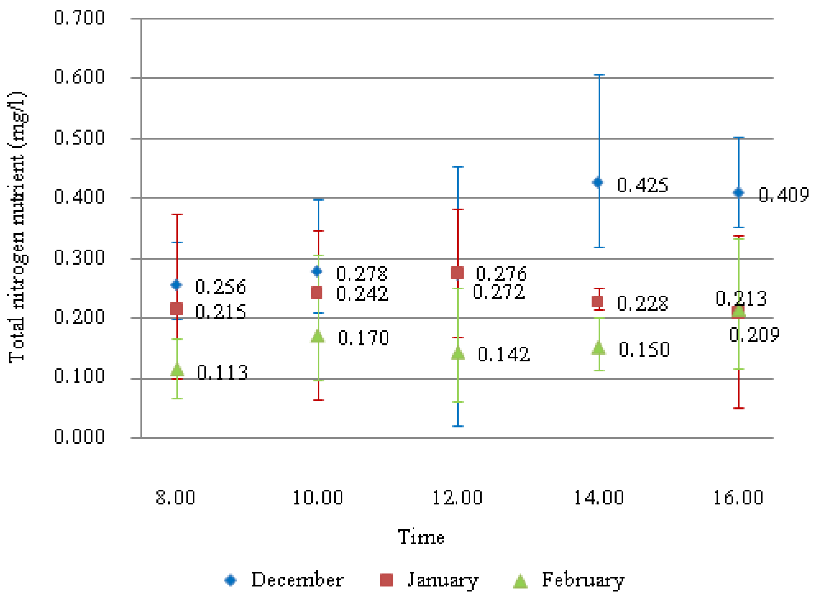

Figure 2. Total nitrogen concentrations in wastewater during December 2008 to February 2009.

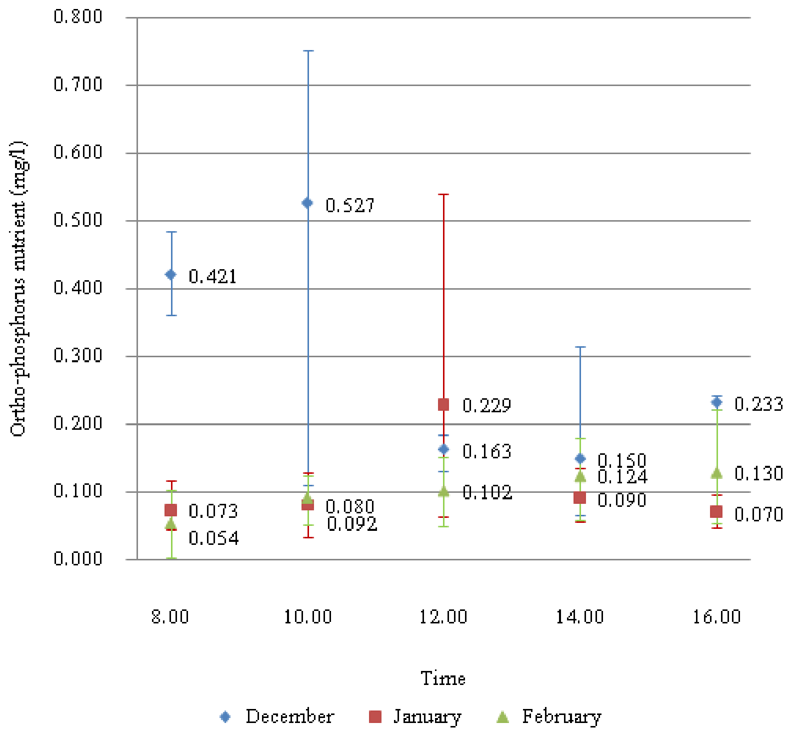

Figure 3 Ortho-phosphorus concentrations during December 2008 to February 2009.

The average total-nitrogen concentration for three months was 0.240±0.085 mg/L, which is lower than that of the wastewater discharge standard of 1.1 mg-N/L [7]. The wastewater can then be directly discharged to natural sources. The fluctuation of ammonia-nitrogen level may be caused by the release of the nutrients through the trout digestion system [8]. Bergero [9] found that a small rainbow trout released 4.3 µg/g/hr of ammonium-nitrogen when feeding at

1.2% of its body weight. The nitrite-nitrogen concentrations were not shown here since they were very low at approximately 0-0.015 mg-N/L.

The average ortho phosphorus concentration for three months was 0.171±0.114 mg/L, which is lower than that of the wastewater discharge standard of 0.4 mg/L [7].

The pH, DO and temperature were determined. The pH of wastewater was in the range of 6.8 and 7.3, which was within the wastewater discharge standard of 6.5 - 8.5 [7]. In addition, this pH range is suitable for rice growing that is between pH 5 and 7.5 [8]. The average DO of wastewater was in a range of 7.0 - 7.3 mg/L. This high DO would be beneficial to crops for fertilization purposes [8].

The average temperatures of wastewater were 15.8 ± 2.0^{o}C and 14.7 ± 1.5^{o}C in December 2008 and January 2009, respectively, while the average temperature increased to 25.7 ± 4.4^{o}C in February 2009. Temperature plays an important role in trout and microorganism metabolic rate, which subsequently affects the release and concentrations of nutrients in wastewater [6]. The total ammonia-nitrogen in February was lower than that of the other two months. It may be due to the metabolic rate of nitrifying bacteria in degrading ammonia is higher as the rate strongly depends on the temperature.

Using the above data to calculate the nutrients in terms of nitrogen and phosphorus for rice crops, the total nitrogen flow was 414.4±81.6 mg/min and the total phosphorus flow was 280.7±68.8 mg/min. In other words, the accumulated nitrogen was 0.479-0.714 kg-nitrogen in a period of 24 hours, while the accumulated phosphorus was 0.304-0.502 kg in a period of 24 hours.

Survey results

Upland rice cultivation in the village was undertaken once a year (May to the beginning November). Two types of fertilizers are applied to the rice fields – agro-chemical fertilizer and organic fertilizers, such as buffalo/cow dung. Agro-chemical fertilizers and water are generally supplied to the rice fields throughout the cultivation period with the exception of the beginning of the formation of rice kernels. Supply of water is stopped one week before harvesting. The application of organic fertilizers, i.e. buffalo/cow dung, to rice fields was done after harvesting for the next season. Table 5 presents the data obtained from rice growers in the village – 2 households using trout farm wastewater and the other 16 households using other sources of water.

The survey results show that the rice production yields between the households utilizing water from the trout farm (Nos.17-18) and other sources were slightly different (Table 5). The average rice yields of the two groups showed fluctuation due to the estimation of data. Households Nos.17-18 began to use trout farm wastewater for rice cultivation and found rice yield increasing in 2004, during which time both households were not adding any fertilizer. In 2006, these households added more fertilizer and production yield continued to increase. A comparison of households who used and did not use wastewater for growing rice revealed that No.17 (w. w/water) had 10 cows and left the cows to graze in the farm for 5 months, thus receiving natural fertilizer, while Household No. 3 (no w/water) had same amount of cows but left the cows on the farm for 6 months. It was found that rice yield of No.17 inclined higher than No.3. Rice production yield was also compared between No.17 and No.15 (who had 12 cows and left them in the field for 5 months) and it was found that No.15 had lower yields than No.17.

Table 5. Data collection from 18 households harvesting Med-Luang variety in the village as fertilizer quantity, cost and rice production yield.

No.	Fertilizer quantity in 2007 (kg/rai)	Fertilizer Cost in 2007 (฿)	Rice production yield (kg/rai)				
			2003	2004	2005	2006	2007
1	NC [a]	NC	-	-	-	437	437
2	NC [a]	NC	-	-	318	359	410
3	NC [a]	NC	-	-	-	517	508
4	NC [a]	NC	-	-	564	564	564
5	NC [b]	NC	536	550	543	564	550
6	NC [a]	NC	-	-	-	444	494
7	12.5 [c]	300	282	282	346	444	409
8	25 [c]	600			480	423	494
9	12.5 [c]	300	423	423	409	458	423
10	6.25 [c]	250	-	-	-	578	564
	NC [b]	NC					
11	30 [c]	720	-	462	-	564	535
12	N	NC	-	-	367	367	395
13	10 [c]	240	-	-	451	451	502
	NC [a]	NC					
14	NC [b]	NC	302	302	282	403	403
15	NC [b]	NC	-	-	-	458	444
16	NC [a]	NC	458	458	458	472	469
17*	NC [a]	NC	470	658	658	771	686
18*	10 [c]	240	361	451	451	508	463
Avg. RPY of growing rice using water from other sources (1-16)			380	394	422	469	475

Remarks: NC = no calculation

-[a] = organic fertilizer from cow dung

-[b] = organic fertilizer from buffalo dung

-[c] = agrochemical fertilizer (16-20-0)

N = no applied fertilizer

- = households growing rice using trout farm wastewater*

Household No.18 (w. w/water) used 10 kg/rai of chemical fertilizer and had higher yields when compared to No. 13 who also used 10 kg/rai of chemical fertilizer and left 3 cows in the rice field for 4 months. Theoretically, the fields of No.13 should have received higher fertilization than No.18. Households Nos.7 and 9 using fertilizer of 12.5 kg/rai still had lower yields than No.18. On the other hand, in 2006-2007, Household No.11 achieved higher yields than No.18, but this required using more fertilizer more than No.18. From this analysis it can be concluded that wastewater from the fish farm provides nutrients that are beneficial for rice plants, can increase yields and reduce the cost of fertilizer. However, any increase or decrease in yields must consider many variables for example, existing nutrients in the soil, weed growth around the rice plants, amount of natural feed available to cows, rice diseases and pests that affect yield, soil hardening from overuse of chemical fertilizer, rice seeds lost during harvesting etc. Nonetheless, it was clear that wastewater had beneficial effects.

Further interviews were conducted to investigate the quality of rice produced. The rice growing with trout farm wastewater produced plants approximately 30 cm taller than the standard height of 120-130 cm. The rice also showed a higher occurrence of tillering (1-3 to

2-5 buds). Tillering in rice is an important agronomic trait for better grain production. Rice tillering occurs in a two-stage process: the formation of an auxiliary bud at each leaf axil and its subsequent outgrowth. Rice produced with wastewater also had ears approximately 1-5 cm longer than the standard 10-15 cm. The rice plants were a lighter green in colour, the ears and paddy were of similar colour, as shown in Figure 4.

Figure 4. Paddy from households using trout farm wastewater for growing (Nos.17-18) and those who used water from other sources (Nos. 2, 4, 12-13).

The use of wastewater from the rainbow trout farm for rice cultivation has an added advantage due to assimilation of nutrients in the rice plant, because ammonium ion (NH_4^+) is the proper form of nitrogen that can be readily taken up by the plant [8].

Further management of wastewater re-use could be established from the measured and collected data. The quantity of recommended compost from the Department of Rice, Ministry of Agriculture and Cooperatives was 600 gm dry weight/rai, with an approximate nitrogen content of about 1.2-2.0% of dry weight [9]. The calculation suggested that the supply of 80 m^3 of wastewater would be required for the area of 1 rai [10, 11]. The total nitrogen from wastewater is about 0.0124-0.0260, disregarding the volatility of nitrogen, and has phosphorus 0.0216-0.0252 kg-P/rai. However, nutrients in the wastewater are lower than the Ministry of Agriculture and Cooperatives suggest – nitrogen 8.6-14 kg-n/rai and phosphorus 5-6 kg/rai [9].

Conclusion

The total wastewater flow rate during December 2008 to February 2009 was approximately 1,834.2±323.2 L/min with an average nitrogen and phosphorus content of 0.240±0.085 mg/L and 0.171±0.114, respectively. Based on the interview data, rice fields using trout farm wastewater showed slight differences in rice production yield and appearance, but a higher ratio of rice tillering. The trout farm wastewater may then be an additional source of nitrogen and phosphorus to the rice fields.

Acknowledgement

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