

# Dissolved Nitrogen Compounds in Integrated Aquaculture Effluent

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## *Abstract*

*Integrated aquaculture utilizing pre-irrigation water will hypothetically increase the levels of dissolved nitrogen products in the resulting effluent. Research was performed to assess the levels of additional nutrients added. The results suggest however, that integrated aquaculture may reduce the amount of nitrogen as nitrate applied to the fields.*

## Introduction

The integration of aquaculture and agriculture in Arizona can be a successful strategy if operational expenses are shared among a diversified crop base. Whole farm economies of scale can therefore result in significant reductions in the per-unit cost of the fish produced thereby increasing marketability and competitiveness (Fitzsimmons, 1985; D'Silva et. al, 1991; Brooks, 1991; Budhabhatti and Maughan, 1991; Brooks, 1992). The integrated aquaculture techniques proposed for Arizona are largely single pass and a non-consumptive use of water. The resulting effluent is enhanced with ammonia, nitrite and nitrate hypothetically reducing the need for additional fertilizer inputs to field crops using this resource as irrigation.

The management of nitrogen fertilizer is a major component of a successful cotton production program. Particular attention must be paid to inputs to minimize downward migration of  $\text{NO}_3\text{-N}$  into the water table (Silvertooth et. al, 1990; Silvertooth et. al. 1991). If aquaculture and agriculture are to be successfully integrated, an operator must know how much additional nutrients are being added to the irrigation by the fish. Research was performed at the University of Arizona Maricopa Agricultural Center in 1990 to assess the levels of nitrogen input by fish culture.

## Materials and Methods

A rectangular 100 x 100 x 4 foot water storage pond was modified for use as a semi-recirculating aquaculture system. The single pond was divided into two 100 x 30 x 4 foot earthen semi-raceways. One raceway was converted into an aquatic macrophyte based biofilter, while the other was retained for fish culture. The system circulated the water through the biofilter at a rate of approximately 400 gallons per minute (gpm) with a total exchange every 6 hrs.

Water for this study was supplied by the Central Arizona Project (CAP). The Total Dissolved Solids (TDS) content of the delivered surface irrigation water was 830ppm  $\pm$  50ppm. Water temperature measured with a standard laboratory thermometer varied from 76° F at the beginning of the study to 83° F at the end with an average daily variation of 5° F. Aeration was supplied 24hr per day by a 3.5 hp regenerative blower.

On June 30, 1990, 2,500 mixed sex tilapia averaging 6 inches in size were stocked. The duration of the study was to be 73 days. The stocks were obtained from Desert Rose Fisheries, and H & J Fisheries at Hyder Arizona. The fish were of one genus and four species and their hybrids (Trewavas 1983, Brooks, 1990):

A. <u>Oreochromis mossambicus</u> X <u>O. urolepis hornorum</u>	Golden Tilapia
B. <u>Oreochromis aureus</u>	Blue Tilapia
C. <u>O. mossambicus</u>	Java Tilapia
D. <u>O. niloticus</u>	Nile Tilapia

At the end of the 73 day time period, the tilapia were harvested and total weights and numbers recorded.

To assess the levels of nutrients added to the effluent from the fish, fresh water input was set at 25gpm for a period of one week for 13 hrs per day. Total water retention time at this level was approximately 8 days. Every other day water samples were taken from the incoming canal water and from the effluent and tested for pH, total ammonia, nitrite and nitrate content. The experiment was then repeated at a fresh water input level of 100 gpm with a water retention time of approximately 2 days.

### Results

On September 11, 1990, 1,200 lbs of fish were harvested from the two net pens totalling 1,645 individuals with an average wt of 0.73lbs  $\pm$  0.23. When the pond was drained, 7 pounds of fingerlings and 21 pounds market sized fish (1lb +) were found. Along with the tilapia, 77lbs of introduced fish were recovered in the open pond. Species included common carp (Cyprinus carpio), channel catfish (Ictalurus punctatus), common carp/ gold fish (Carassius auratus) hybrids, green sun fish (Chaenobrytrus cyanellus), and bluegills (Lepomis macrochirus) (Minckley, 1973). The total fish harvest was 1,305 pounds with an estimated stocking density of 0.07 lbs of fish per ft<sup>3</sup>.

#### Ammonia

As seen in Table 1, there was an increase in the amount of ammonia in the effluent water from the fish over the incoming water from the CAP. There was little difference between the 25gpm and 100gpm treatments for total ammonia. The ambient level of total ammonia for the CAP water for the 25gpm treatment was 0.23  $\pm$  0.33ppm. At an average pH of 8.69, and a temperature of 82° F, the unionized fraction of the ammonia is calculated to be 0.060 ppm (Tucker and Robinson, 1990). Using the formulae (ppm NH<sub>4</sub> / (18/14) = ppm NH<sub>4</sub>-N) + (ppm NH<sub>3</sub> / (17/14) = ppm NH<sub>3</sub>-N) and (ppm NH<sub>3</sub>-N \* 2.7 = pounds of N applied per acre foot of water), total ammonia nitrogen input by the Central Arizona Project water equaled 0.505 pounds. Total ammonia input from the effluent equaled 0.45  $\pm$  0.38 ppm or 0.985 pounds of nitrogen per acre foot of water. The amount of ammonia added by the fish over ambient levels was therefor 0.22 ppm or 0.480 pounds of ammonia nitrogen per acre foot of water (Table 1. and Table 5.)(Jack Watson, 1991; Personal Communication).

For the 100 gpm treatment, the mean ambient level was 0.18  $\pm$  0.05ppm (0.397 lbs N/ac ft<sup>3</sup>), and 0.42  $\pm$  0.18ppm (0.919 lbs N/ ac ft<sup>3</sup>) for the effluent. The increase in the nitrogen level for this treatment was 0.24 ppm or 0.522 pound of N applied per acre foot of water.

#### Nitrite

At a flow rate of 25gpm and a retention time of 8 days, there was an increase in the mean levels of nitrite (NO<sub>2</sub>) in the fish effluent over the incoming CAP water of 0.34 ppm  $\pm$  0.12, a change of over 550%. There was little difference between the levels of nitrate in the CAP and the effluent at a flow rate of 100gpm, therefor the results were not pooled.

For the 25gpm treatment levels of ambient nitrite averaged 0.06  $\pm$  0.03ppm or 0.049 pounds of nitrite nitrogen per acre foot of water applied. Levels of nitrite in the effluent averaged 0.40  $\pm$  0.15ppm or 0.329 pounds of nitrogen per acre foot of water, an increase of 0.280 pound of nitrogen per acre foot (Table 2. and Table 5.)

The amount of nitrite nitrogen added to the effluent by the 100 gpm treatment was considerably lower than for the 25 gpm. Ambient levels for this treatment averaged 0.03  $\pm$  0.01ppm (0.025 lb N/ac ft<sup>3</sup>), while mean effluent levels were 0.08  $\pm$  0.02 ppm (0.066 lb N/ ac ft<sup>3</sup>). The resulting increase in this circumstance was 0.041 pounds of nitrogen per acre foot of water.

## Nitrate

The mean amount of nitrate in the effluent was than the amount dissolved in the incoming CAP irrigation water. For the 25 gpm treatment, ambient levels of  $\text{NO}_3$  averaged  $26.86 \pm 11.26$  ppm ( $16.376$  lb N/ac  $\text{ft}^3$ ). The amount of nitrate in the effluent averaged  $17.98 \pm 4.74$  ppm ( $10.962$  lb N/ac  $\text{ft}^3$ ) a reduction of 5.414 pounds of nitrate nitrogen per acre foot of water applied over the CAP.

Ambient levels of nitrate averaged  $13.45 \pm 1.97$  ppm ( $8.20$  lbs N/ ac  $\text{ft}^3$ ). The mean nitrate level in the effluent was  $13.29 \pm 3.77$  ppm ( $8.103$  lbs N/ ac  $\text{ft}^3$ ) a decrease of 0.097 pounds of nitrogen per acre foot.

## Total Dissolved Nitrogen Levels

Pooling the results of the 25 gpm treatment, levels of total nitrogen equaled 16.930 pounds per acre foot of CAP water and 12.227 pounds of nitrogen per acre foot for the effluent, a net decrease of 4.703 pounds of nitrogen or 28%. For the 100gpm treatment, the mean ambient level of nitrogen totaled 8.622 pounds per acre foot while the mean effluent level was 9.066, a net increase of 0.466 lbs or 5%.

## Discussion

These results suggest the longer the holding period, the lower the amount of nitrogen released into the effluent. There are several possible explanations for the reduced nitrogen content of the effluent. The nitrification/ de-nitrification process in ponds is very complex. It is well with in reason the high pH increased the rate of ammonia volatilization into the atmosphere. Without ammonia to utilize the nitrogen oxidizing bacteria cannot produce nitrite and later nitrate (Tucker and Robinson, 1991). This does not however explain the reduction in nitrate levels over the ambient.

It is possible that the nitrate was absorbed by the phytoplankton and the aquatic macrophytes growing within the system. The technique used to test for nitrate would not count ammonia incorporated into plant amino acids. If this is so, then a significant amount of nitrogen is passing through the effluent in the form of plant biomass. The effect of the decay of these plants on the nutrient levels of the fields receiving the effluent water should be carefully examined.

## Acknowledgments

This project was supported by extension research funds from the University of Arizona, Department of Veterinary Science. Invaluable support was also provided by Dr. Cy Card, Dr. Roy Rauschkolb, Dr. Ed Bicknell, Mr. Pat Murphree, Dr. Robert Roth, Mr. Tony Porti, and Ms. Jennifer Budhabhatti. Special thanks for assistance, equipment and facilities goes to Keith Leuwan and the scientists at the Brookhaven National Laboratory's FACE project, Gary John and Jim Haggard of H & J fisheries and Hugh and Joe Johnson of Desert Rose Fisheries. Special acknowledgments go to Dr. Jack Watson for his knowledge in water chemistry and Dr. Dan Warren for assistance with the statistical analysis.

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TABLE 1. NH<sub>4</sub> data.

Date	Sample Location		Effluent	Difference
	CAP Water			
25gpm water flow treatment.				
8/15	0.61		0.89	0.28
8/17	0.03		0.26	0.23
8/21	0.06		0.21	0.15
ppm	$\overline{0.23} \pm 0.33$		$\overline{0.45} \pm 0.38$	$\overline{0.22} \pm 0.15$
Lbs N/ ac ft <sup>3</sup>	0.505		0.985	0.480
100gpm water flow treatment.				
8/27	0.13		0.31	0.18
8/29	0.18		0.31	0.13
8/30	0.22		0.63	0.41
ppm	$\overline{0.18} \pm 0.05$		$\overline{0.42} \pm 0.18$	$\overline{0.24} \pm 0.15$
Lbs N/ ac ft <sup>3</sup>	0.397		0.919	0.522

TABLE 2. NO<sub>2</sub> data.

Date	Sample Location		Effluent	Difference
	CAP Water			
25gpm water flow treatment.				
8/15	0.05		0.43	0.38
8/17	0.09		0.53	0.44
8/21	0.03		0.23	0.20
ppm	$\overline{0.06} \pm 0.03$		$\overline{0.40} \pm 0.15$	$\overline{0.34} \pm 0.12$
Lbs N/ ac ft <sup>3</sup>	0.049		0.280	0.231
100gpm water flow treatment.				
8/27	0.02		0.09	0.07
8/29	0.03		0.06	0.03
8/30	0.03		0.08	0.03
ppm	$\overline{0.03} \pm 0.01$		$\overline{0.08} \pm 0.02$	$\overline{0.05} \pm 0.02$
Lbs N/ ac ft <sup>3</sup>	0.025		0.066	0.041

TABLE 3. NO<sub>3</sub> data.

Date	Sample Location		Difference
	CAP Water	Effluent	
<b>25gpm water flow treatment.</b>			
8/15	43.65	20.62	-23.03
8/17	20.83	11.06	-01.37
8/21	20.01	21.42	+01.41
ppm	$\overline{26.86} \pm 11.26$	$\overline{17.98} \pm 4.74$	$\overline{-10.46} \pm 12.23$
Lbs N/ ac ft <sup>3</sup>	16.376	10.962	-05.414
<b>100gpm water flow treatment.</b>			
8/27	15.37	17.43	+02.06
8/29	11.44	10.07	-01.37
8/30	13.55	12.37	-01.18
ppm	$\overline{13.45} \pm 1.97$	$\overline{13.29} \pm 3.77$	$\overline{-00.16} \pm 1.93$
Lbs N/ ac ft <sup>3</sup>	08.200	08.103	-00.097

TABLE 4. pH data.

Date	Sample Location	
	CAP Water	Effluent
<b>25gpm water flow treatment.</b>		
8/15	8.82	8.71
8/17	8.65	8.80
8/21	8.60	8.41
0.12	$\overline{8.64} \pm 0.17$	$\overline{8.69} \pm 0.12$
<b>100gpm water flow treatment.</b>		
8/27	8.53	8.67
8/29	8.58	8.75
8/30	8.75	8.89
	$\overline{8.62} \pm 0.12$	$\overline{8.77} \pm 0.11$
Total	$\overline{8.64} \pm 0.11$	$\overline{8.69} \pm 0.15$

**TABLE 5. Conversion Formulae**

**Pounds of nitrogen per acre foot of water applied = ppm(N) \* 2.7**

**ppm NH<sub>3</sub>-N = ppm NH<sub>3</sub>/(17/14)**

**ppm NH<sub>4</sub>-N = ppm NH<sub>4</sub>/(18/14)**

**ppm NO<sub>2</sub>-N = ppm NO<sub>2</sub>/(46/14)**

**ppm NO<sub>3</sub>-N = ppm NO<sub>3</sub>/(64/14)**

**After Watson, 1991.**