AACL BIOFLUX

Aquaculture, Aquarium, Conservation & Legislation
International Journal of the Bioflux Society

Dynamics of the level and ratio of nitrogen and phosphorus in carp ponds water: the effect of mineral fertilizers upon its quality

Liliana Hadjinikolova, and Angelina Ivanova

Institute of Fisheries and Aquaculture, Plovdiv, Bulgaria,
Corresponding author: L. Hadjinikolova, lhadjinikolova@yahoo.com

Abstract. The purpose of this investigation is to establish the dynamics of nitrogen and phosphorus level variation and of their ratio after mineral fertilizers application in water. After mineral fertilizers application into the ponds, the real biogenic quantities in water have increased by 2.8-10 times for nitrogen, and by 2-28 times for phosphates, at scheduled nitrogen levels of 5-7 mg L^{-1} and nitrogen/phosphorus ratio of 10:1, 16:1 and 20:1, respectively. During the period 1st – 3rd day after fertilizer application, optimum nitrogen levels have been preserved of 2.60 – 5.79 mg L^{-1}. A tendency of residual biogenic quantities decrease in the water has been observed from the 10th to the 30th day after fertilizer application.

Key Words: water quality, mineral fertilizers application, nitrogen, phosphorus, ratio.

Абстракт. Целта на настоящото проучване е да се установи динамиката на изменение на нивото на азота и фосфора, и тяхното съотношение, след минерално торене. След внасянето на минералните торове в басейните реалните количества на биогените във водата се увеличават с 2.8-10 пъти за азота и с 2-28 пъти за фосфатите, при планирани нива на азота от 5 до 7 mg L^{-1}, на фосфора от 0.35 до 0.5 mg L^{-1} и съотношения азот/фосфор съответно 10:1 ,16:1 и 20:1. В периода от 1-я до 3-я ден след торенето се запазват оптимални нива на азота от 2.60 до 5.79 mg L^{-1}. Тенденция на намаляване на остатъчните количества на биогените във водата се наблюдава от 10-я до 30-я ден след торенето.

Ключови думи: качество на водата, минерално торене, азот, фосфор, съотношение.

Rezumat. Scopul prezentului studiu este de a stabili dinamica variaţiei nivelului de azot şi de fosfor precum şi a raportului dintre acestea, după aplicarea în apă a substanţelor mineralizante. În urma aplicării în lacuri a fertilizanţilor minerali, cantitatea agenţilor biogeni din apă a crescut între 2,8-10 ori în ceea ce priveşte azotul şi între 2 şi 8 ori pentru fosfaţi , la nivele înregistrate ale azotului de 5-7 mg L^{-1} şi ale raportului azot/fosfor de 10:1, 16:1 şi 20:1, respectiv.Pentru perioada cuprinsă între prima şi a treia zi după aplicarea fertilizanţilor, a fost menţinut un nivel optim a azotului de 2.60 – 5.79 mg L^{-1}. O tendinţă de scădere a cantităţilor reziduale a agenţilor biogeni din apă a fost observată între cea de a zecea şi cea de a treizecea zi după fertilizare.

Cuvinte cheie: calitatea apei, aplicarea de minerale fertilizante, azot, fosfor, raport.

Introduction. The natural fish productivity of water ponds is determined by plankton and benthos quantity, which serve as food for different fish species. The growth of the fish species exemplaries depends on the availability of the main biogenic elements, *such as* nitrogen and phosphorus. The controlled regulation and addition of mineral fertilizers can increase the natural productivity of water ponds (Culver et al 1993; Abbas 2001; Chumchal et al 2004, 2005; Wang et al 2008). Thus, fertilizer application is one of the most often employed enhancement activities in fish farming practice (Yu & Fan 1991; Jana & Chakrabarty 1997; Culver et al 2003; Dasgupta et al 2008).

The balance between nitrogen and phosphorus depends not only on their ratio in the water pond, but also on the processes controlling biogenic rotation and on their distribution in the aquatic ecosystem (Knosche et al 2000). Their presence in sufficient

quantity is completely necessary for the normal life development in the aquatic ecosystem.

The investigations done by many authors have taken into consideration besides biogenic quantity of nitrogen and phosphorus, the ratio N:P and the phytoplankton growth (Baranov 1982; Miheeva 1983). It has been reported that the most intensive phytoplankton growth has been observed at nitrogen contents of 1.5 – 2.0 mg L^{-1} and at phosphorus contents of 0.15 – 0.20 mg L^{-1}, at a ratio of 10:1, while in other investigations the ratio of 15:1 has been determined as normal.

Generally, the biogenic substances content varies with the different water ponds. The dosage for nitrogen and phosphorus fertilizers' application, in order to reach nitrogen concentration of 2 mg L^{-1} and phosphorus concentration of 0.5 mg L^{-1}, has been calculated after the nitrogen and phosphorus contents in the analyzed water. The problem of biogenic exhaustion time and fertilization rate frequency is also important, with the aim of keeping up the level and the ratio stimulating the natural productivity of ponds and most of all of plankton. In this respect, the purpose of our investigation is to establish the dynamics of nitrogen and phosphorus level variation and of their ratio after mineral fertilizers application in the water, as the first stage for determining fertilizers application rate frequency and for stimulating the natural productivity in carp water ponds.

Material and Method

Water Ponds. In order to attain the aims of the present investigation, we used: 7 carp ponds with a single area of 1.3 dka – 3.8 dka, located in the Experimental Base of the Institute of Fisheries and Aquaculture (IFA) – Plovdiv. The ponds were divided into three groups for investigation of the dynamics of nitrogen and phosphorus level variation, at a ratio of N/P, as follows:

Group I – at a ratio of N/P 10:1 (ponds No 19, 20, and 21);

Group II - at a ratio of N/P 20:1 (ponds No 16 and 17);

Group III - at a ratio of N/P 16:1 (ponds No 6 and 8).

The ponds fish stocking involved introduction of one-year old carp - *Cyprinus carpio* Linnaeus, 1758 - at population density of 45-50 Nb.dka^{-1}, bighead carp larvae of *Hypophthalmichthys nobilis* (Richardson, 1845), which grew up, at a density of 2000 Nb.dka^{-1} as well as 20-days` old little carp alevins *Cyprinus carpio* Linnaeus, 1758 at a density of 6000 – 8000 Nb.dka^{-1}. During the vegetation period, fish feeding involved using sunflower groats and wheat. The fish feeding rations were determined on the basis of monthly percent feed distribution.

Mineral Fertilizers and Calculation of Fertilizers' Dosage Application. The percent of active substance in the used mineral fertilizers varied as follows:

Nitrogen fertilizer – ammonium nitrate (NH_4NO_3) – total nitrogen-34.4%; ammonium nitrogen – 17.0%; nitrate nitrogen – 17.4%.

Phosphorus fertilizer – super-phosphate – water- and citro-soluble P_20_5 – 45.5%; water soluble P_20_5 – 43% minimum; free acid (as P_20_5) – 3.5% maximum.

The required quantity of nitrogen and phosphorus fertilizers was calculated after determining the nitrogen and phosphorus quantity in the water, employing the following formula:

$$A = (B-C).D/P \times 100, \text{ where:}$$

A – required (kg.dka^{-1}) fertilizer quantity; B – biogenic element required quantity in the sample, mg L^{-1}; C – biogenic element quantity in the sample, mg L^{-1}; D – meaning depth of the water pond, m; P – biogenic quantity in the fertilizer, %.

During the experiments in the vegetation period, the water physical and chemical parameters in the experimental ponds were recorded, with the purpose of quality assessment. The water samples for analysis were taken from the water layer of the ponds (up to 0.5 m in depth), in time intervals of 8.30 – 9.30 hours, from June till

September. The physical-chemical water examinations in the experimental ponds were carried out according to the following schedule:

- the samples for determining temperature and dissolved oxygen in water indices were taken once per week, and those for determining pH, chemical oxygen demand (COD) and biogenic elements level indices – twice per month;
- in the period before fertilizer application and up to 30^{th} day after fertilizer application of the ponds, the indices traced were determined three times per week.

Temperature (t^oC) measurement and determination of the quantity of dissolved oxygen in water (mg L^{-1}) were achieved by means of microprocessor oxymeter, type WTW 315i/SET. pH level was reported by means of pH-meter, type MV 88. Ammonium nitrogen ($N\text{-}NH_4^+$), mg L^{-1} concentration was spectro-photometrically measured, using Nesler`s reagent after (BSS-341377) - the Bulgarian State Standard (ISO synchronized), and the nitrate nitrogen ($N\text{-}NO_3$), mg L^{-1} – spectro-photometrically, after BSS-3758-85 (ISO synchronized). Phosphorus concentration (phosphate phosphorus $P\text{-}PO_4^{3-}$), mg L^{-1} was spectro-photometrically measured, using molybdenic reagent (BSS 7210-838). Chemical oxygen demand (mg $0.l^{-1}$) was measured after an analytical standard method (BSS-3413-77).

During the experiments, the dynamics of hydro-biological parameters Chlorophyll-*a*, phytoplankton and zooplankton was traced. The results from the investigations will be published in future publications.

Results and Discussion. The average seasonal, minimum and maximum values of the limiting physical and chemical water parameters during the period June-September have the following characteristics:

Water Temperature. The average water values were within the limits of 21.3 – 21.7°C for the Group I and for the Group II ponds, with registered water morning temperatures maximum of 24.0°C – 25.2°C and 17.1°C – 18.2°C, for the Group III ponds, respectively, with registered water morning temperatures, maximum of 19.0°C – 21.4°C. The data indicated that within the period June-August, water temperature was favorable for the given fish species breeding.

Hydrogen Index (pH). The average seasonal values concerning the traced ponds were within the range of 7.8 – 8.0 for the Group I and for the Group II ponds, and 8.02 – 8.93 for the Group III ponds, respectively.

Dissolved Oxygen. The level of the dissolved oxygen in water was within the optimum limits for the fish species reared during the whole vegetation period. The average seasonal values varied within the limits of 5.9–8.6 mg L^{-1} for the Group I and for the Group II ponds, and 5.1 – 9.3 mg L^{-1} for the Group III ponds, respectively.

Chemical oxygen demand. The reported average values for permanganate oxidability during the vegetation period were within the limits of 10.55 – 18.97 mg L^{-1} for the Group I and for the Group II ponds, and 8.96–14.67 mg L^{-1} for the ponds of the third group, respectively. In all experimental ponds, oxygen chemical demand values were within the technological norms for the fish species bred.

The values of the physical-chemical water parameters, before the main fertilization of the ponds, were shown in Table 1. The values of the traced reported indices were favorable for the application of mineral fertilizers. The biogenic elements - nitrogen and phosphorus level, as well as their ratio (N/P) (see Table 2) were established, too. They varied within the limits of 3.5-9.5:1 for the Group I, 58-95:1 for the Group II, and 6.4-11.3:1 for the Group III ponds.

Table 1

Values of the main physical and chemical parameters of ponds before fertilizers application

Pond №	*T°C*	*O_2 (mg L^{-1})*	*pH*	*Chemical oxygen demand (mg L^{-1})*
19^{I}	20.9	6.7	7.6	10.55
20^{I}	21.0	4.7	8.4	9.7
21^{I}	2.1	5.4	7.9	12.7
16^{II}	21.3	5.9	7.8	10.60
17^{II}	21.7	4.8	8.0	11.70
6^{III}	22.1	7.4	8.91	11.43
8^{III}	21.9	12.8	9.67	19.81

I – First group; II- Second group; III- Third group

Considering the data presented above, calculation of required quantities of the nitrogen and phosphorus fertilizers were achieved, in order to reach the recommended levels and ratios of nitrogen and phosphorus in the water (see Table 2). By means of single fertilization application we reached the ratio of N/P 10:1 in Group I ponds No 19-21, the ratio of N/P 20:1, in Group II ponds No 16 and 17,and the ratio of N/P 16:1 in III group ponds No 6 and 8.

Table 2

Level and ratio of biogenes

Pond №	*Level and ratio of biogenes before fertilizers application*			*Scheduled quantities and ratios of biogenes*		
	N mg L^{-1}	P mg L^{-1}	N/P	N mg L^{-1}	P mg L^{-1}	N/P
19^{I}	0.95	0.10	9.5	5.0	0.50	10
20^{I}	1.65	0.22	7.5	5.0	0.50	10
21^{I}	0.45	0.13	3.5	5.0	0.50	10
16^{II}	0.95	0.01	95	7.0	0.35	20
17^{II}	1.75	0.03	58.3	7.0	0.35	20
6^{III}	2.04	0.18	11.3	7.0	0.45	16
8^{III}	1.28	0.20	6.4	7.0	0.45	16

I – First group; II- Second group; III- Third group

The dynamics of nitrogen and phosphorus level variation and of their ratio up to 30^{th} day after a single fertilizer's application, at a ratio of nitrogen/phosphorus 10:1 (Group I), 20:1 (Group II) and 16:1 (Group III) was presented in Table 3.

Concerning the Group I ponds, during the period from the1st to the 3rd day after fertilizer's application, nitrogen optimum level was preserved (3.43 – 4.56 mg L^{-1}), and inorganic phosphorus level varied within the limits of 0.16 – 0.40 mg L^{-1}. The reported ratio N/P varied within the limits of 11.2:1 – 22:1.

From the 10th to the 30th day, a tendency of decrease of the residual of biogenic quantities in the water was observed. Nitrogen quantity on the 10th day registered 38%, on the 20th day – 24%, and on the 30th day – 12% compared to the level reported during the 1st day after fertilizer's application. Phosphates level on the 30th day registered 32.5-40% compared to the level that was reported during 1st day after fertilizer's application.

For the Group II ponds, during the period from the 1st to the 3rd day after fertilizer's application, nitrogen optimum level was preserved (2.6 – 5.78 mg L^{-1}), and ratio N/P of 17:1 – 20:1. The inorganic phosphorus level was within the limits of 0.12 – 0.30 mg L^{-1}.

From the 10th to the 30th day, a tendency of decrease in the residual biogenic quantities in the water was observed. Nitrogen quantity on the 10th day was 22-28%, on the 20th day – 16-27.6%, and on the 30th day – 12.7-18% compared to the level, reported during 1st day after fertilizer's application. Phosphates level on the 30th day was 43-60% compared to the level reported during the 1st day after fertilizer's application.

In what concerns the Group III ponds, during the period from the 1st to the 3rd day after fertilizer's application, nitrogen optimum level was preserved (3.27 – 5.79 mg L^{-1}). Phosphorus level was reported within the limits of 0.24 – 0.40 mg L^{-1} and ratio N/P of 11.3:1 – 14.8:1.

From the 10th to the 30th day a tendency of decrease in the residual biogenic quantities of water was observed. Nitrogen quantity on the 10th day registered 23.6-28.7%, on the 20th day – 23.8-27.6%, and on the 30th day – 18.9-21.4% compared to the level, reported during the 1st day after fertilizer's application. Phosphates level on the 30th day registered 51.3-75% compared to the level, reported during the 1st day after fertilizer's application.

Data analysis indicates that up to the 30th day after fertilizer's application, nitrogen exhaustion maintained within the limits of 81.1-88.7% for the separate pond groups, which led to the decrease in its absolute values up to 0.51-1.23 mg L^{-1}. Concerning phosphates, there was a tendency for a slower exhaustion and for preservation of relatively higher levels for the same period. The nitrogen exhaustion in the period between the 10th to the 30th day led to ratio N/P, decreasing within the limits of: 3.6:1 – 4.5:1 for the Group I ponds, 5.8:1-6.4:1 for the Group II ponds and 4.1:1-5.5:1 for the Group III ponds.

Table 3

Nitrogen and phosphorus level and ratio variation after fertilizer application

P	*Number of days after fertilizer application*														
o	1			3			10			20			30		
n	N	P	N/P	N	P	N/P	N	P	N/P	N	P	N/P	N	P	N/P
d *№*	mg L^{-1}	mg L^{-1}		mg L^{-1}	mg L^{-1}		mg L^{-1}	mg L^{-1}		mg L^{-1}	mg L^{-1}		mg L^{-1}	mg L^{-1}	
19^{I}	4.51	0.40	11.3	3.55	0.22	16	1.74	0.28	8.7	1.09	0.22	5.0	0.57	0.16	3.6
20^{I}	4.51	0.39	11.6	3.55	0.16	22	1.70	0.20	9.4	1.10	0.18	6.1	0.51	0.14	3.6
21^{I}	4.48	0.40	11.2	3.43	0.22	15.6	1.72	0.20	8.6	1.06	0.18	5.9	0.58	0.13	4.5
16^{II}	5.53	0.28	19.8	2.60	0.12	20	1.22	0.15	8.1	0.89	0.16	5.5	0.7	0.12	6.4
17^{II}	5.78	0.30	19.7	3.35	0.20	17	1.64	0.22	8.2	1.6	0.25	6.4	1.04	0.18	5.8
6^{III}	5.79	0.40	14.5	3.39	0.30	11.3	1.66	0.38	4.4	1.60	0.35	4.8	1.23	0.30	4.1
8^{III}	5.76	0.39	14.8	3.27	0.24	13.6	1.36	0.30	4.5	1.37	0.30	4.6	1.09	0.20	5.5

After mineral fertilizers application to the ponds, the real biogenic quantities in the water increased by 2.8-10 times for nitrogen and by 2-28 times for phosphates.

The data reveal that from the 3rd to the 10th day after fertilizer's application, nitrogen level decreased up to 1.36-1.75 mg L^{-1} at scheduled levels regarding the separate ponds 5-7 mg L^{-1}. The results indicate that in order to maintain an optimum nitrogen level of minimum 2.0 mg L^{-1} the next nitrogen fertilizer application to the ponds should be realized after the 10th day. An important condition is represented by the water physical and chemical parameters, that determine water quality to be within the technological norms for breeding the given fish species.

Exhaustion of phosphates was slower, leading to the remark that phosphorus fertilizer application should be achieved in concordance to nitrogen quantity and nitrogen/phosphorus ratio, which should be maintained in the ponds according to the observed demand.

The present experiments outlined that, within a single addition of mineral nitrogen and phosphorus fertilizers to the fish-breeding ponds, the physical and chemical parameters of the water are not deteriorated. During the vegetation period, the factors limiting its quality were preserved within the limits of technological norms.

Conclusion. After mineral fertilizer application to ponds, the real biogenic quantities in the water increased by 2.8-10 times for nitrogen and by 2-28 times for phosphates, at scheduled nitrogen levels 5-7 mg $L^{-1}$and nitrogen/phosphorus ratio of 10:1, 16:1 and 20:1, respectively.

During the period 1st – 3rd day after fertilizer application, optimum nitrogen levels were preserved at 2.60 – 5.79 mg L^{-1}. A decrease tendency for residual biogenic quantities in the water was observed from the 10th to the 30th day after fertilizer addition.

It was observed that up to the 30th day after fertilizer's application: Phosphates level is 32.5-75% compared to the level reported during the 1st day after fertilizer application; Nitrogen exhaustion is within the limits of 81.1-88.7% compared to the level reported during the 1st day after fertilizer application for the separate groups of ponds. This led to the decrease of its absolute values from 0.51 to 1.23 mg L^{-1}; The ratio N/P decreased within the limits of: 3.6:1 – 4.5:1 for Group I ponds, 5.8:1 – 6.4:1 for Group II ponds and 4.1:1 – 5.5:1 for Group III ponds.

References

Abbas G., 2001 Effect of NPK fertilization on the physicochemical characteristics of water and soil and on the dry weight of planktonic and benthic biomass in carp ponds. Indian Journal of Animal Sciences 71(6):597-603.

Baranov I.V., 1982 [Fundamentals of Hydrochemistry Bioproduction]. Light and Food Industries, pp. 109. [In Russian]

Chumchal M. M., Drenner R. W., 2004 Interrelationships between phosphorus loading and common carp in the regulation of phytoplankton biomass. Archiv Fur Hydrobiologie 161(2):147-158.

Chumchal M. M., Nowlin W. H., Drenner R. W., 2005 Biomass-dependent effects of common carp on water quality in shallow ponds. Hydrobiologia 545271-545277.

Culver D. A., Babcock-Jackson U., Li H., Wu L., Zhang L., Gu L., Wang J. X., Guan M., Chang J., 2003 Evaluation of inorganic nitrogen and phosphorus fertilization techniques for carp ponds. In: Proceedings of the Third World Fisheries Congress, Phillips B., Megrey B.A., Zhou Y. (eds.), pp. 38237-38246.

Culver D., Geddes M., 1993 Limnology of rearing ponds for Australian fish larvae: relationships among water quality, phytoplankton, zooplancton and the growth of larval fish. Austr J Mar Freshwater Res 44:537-551.

Dasgupta S., Pandey B. K., Sarangi N., Mukhopadhyay P. K., 2008 Evaluation of water productivity and fish yield in sewage-fed vis-a-vis fertilized based carp culture. Bioresource Technology 99(9):3499-3506.

Jana B. B., Chakrabarty D., 1997 Relative status and contribution of sediment phosphorus and nitrogen in carp culture system fertilized with various combinations of rockphosphate. Aquaculture Research 28(4):247-255.
Knosche R., Schreckenbach K., Pfeifer M., Weissenbach H., 2000 Balances of phosphorus and nitrogen in carp ponds. Fisheries Management and Ecology 7(1-2):15-22.
Miheeva T. M., 1983 [Succession of Species in Phytoplankton: Determining Factors, Minsk]. Publ. of BGU "Lenin", pp. 69. [In Russian]
Wang H. J., Liang X. M., Jiang P. H., Wang J., Wu S. K., Wang H. Z., 2008 TN : TP ratio and planktivorous fish do not affect nutrient-chlorophyll relationships in shallow lakes. Freshwater Biology 53(5):935-944.
Yu M., Fan Z. Y., 1991 Nitrogen and phosphorus loads and water-quality model of Miyun Reservoir with carp cage culture. In: Environmental Hydraulics, Lee J. H. W., Cheung Y. K. (eds.), 1:21075-21080.

Received: 18 March 2009. Accepted: 16 April 2009. Published online: 16 April 2009.
Authors:
Liliana Hadjinikolova, Institute of Fisheries and Aquaculture, 248 V. Levski Str., Plovdiv 4003, Bulgaria, e-mail: lhadjinikolova@yahoo.com
Angelina Ivanova, Institute of Fisheries and Aquaculture, 248 V. Levski Str., Plovdiv 4003, Bulgaria.
How to cite this article:
Hadjinikolova L., Ivanova A., 2009 Dynamics of the level and ratio of nitrogen and phosphorus in carp ponds water: the effect of mineral fertilizers upon its quality. AACL Bioflux 2(2):209-215.
Printed version: ISSN 1844-8143
Online version: ISSN 1844-9166 available at: http://www.bioflux.com.ro/docs/2009.2.209-215.pdf
Submitted and accepted also in the official program of International Symposium ACVAPEDIA 2009.