Archives of Polish Fisheries	Vol. 1	Fasc. 2	167 - 176	1993

MODEL STUDIES ON A RECIRCULATION SYSTEM WITH A ROTATING BIOLOGICAL FILTER FOR FISH FATTENING

PART II - MODEL STUDIES OF A BIOLOGICAL DRUM FILTER COOPERATING WITH A MECHANICAL FILTER

Ryszard Kolman

The Stanisław Sakowicz Inland Fisheries Institute in Olsztyn

A b s t r a c t. Basing on the results from a series of studies on a rotating biological filter some changes were made in the rotor construction, so that its relative surface increased to 1328 m^2/m^3, and a model pressure mechanical filter was included in the recirculation system. Statistical analyses of the experimental data showed that the RBF was characterized by maximal capacity to oxidize ammonia of 55.66 mg $N\text{-}NH_4/m^2$/day. Use of the mechanical filter reduced the amount of suspended matter from about 30 mg/l to about 4 mg/l.

Key words: FISH REARING, WATER PURIFICATION, RECIRCULATION SYSTEM, ROTATING BIOLOGICAL FILTER

INTRODUCTION

The results of preliminary studies presented in Part I of this paper revealed that it was necessary to increase the active surface of the filter rotor due to a too low dynamics of nitrifying bacteria development and consequently dangerous increase of ammonia and nitrite content in water. Moreover, a decrease of pH value was also observed (to 6.0) pointing to unfavourable conditions for the development of nitrifying bacteria (Haugh and McCarty 1971, Weaton 1977). Lack of mechanical filter in the recirculation system resulted in excessive amounts of suspended matter in water.

The observed processes caused deterioration of water quality in the system, so that it became necessary to modernize it. This was achieved changing construction of the rotor of the biological filter and introducing a mechanical filter.

MATERIAL AND METHODS

Studies were carried out in the model recirculation system described in Part I. The system was additionally equipped with a mechanical filter (Fig. 1). An increase of the relative rotor surface (1328.82 m^2/m^3) was obtained using polyethylene net to envelope particular sections of PCV drainage pipes of 50 mm in diameter.

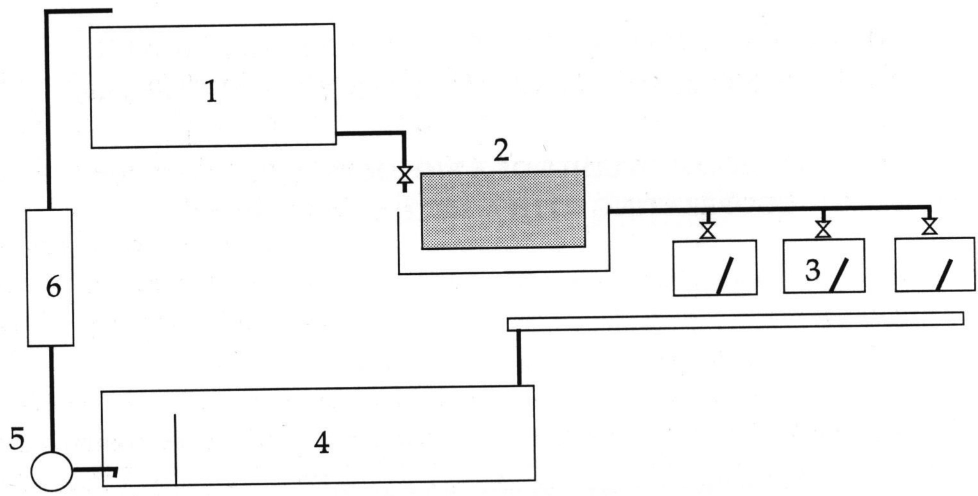

Fig. 1. Diagram of equipment for the recirculation system for fish rearing. 1 - lower retention tank, 2 - biological rotating filter, 3 - rearing tank, 4 - settling tank, 5 - water pump, 6 - pressure mechanical filter

A model rapid mechanical filter was characterized by a complex structure of the substrate:

– upper layer consisted of a diatomite gravel of particle diameter 1.2 - 2.0 mm

– lower layer consisted of quartz sand, the granule size being 0.6 - 0.8 mm Use of two layers with different particle size and different weight resulted in the fact that the filter worked with the whole substrate volume, and the layers did not mix during back washing (Granops 1989). Both layers were 150 mm thick. They were placed on a supporting layer in a cylindrical container 420 mm in diameter and 550 mm high.

Water circulation system (Fig. 1) was based on a pressure pump of capacity 110 l/min, the 10 m water column being lifted. The pump was steered with a level control installed in the upper retention tank.

One rearing tank was stocked with silver carp fry (243 individuals of average weight 29.6 g), the other with common carp (28 individuals of average weight 714 g). The fish were fed with carp pellets. Pellets for silver carp were grounded. Daily food ration was 1.5% of body weight.

Water temperature in the recirculation system ranged from 23 to 25°C throughout the experiment, and water flow was 60 l/min.

RESULTS

The nitrification process started practically since the first day of the experiment. This was reflected in the curves describing changes in the concentration of ammonia, nitrites and nitrates (Fig. 2). Ammonia showed a slightly growing trend, while nitrite content first increased to about 0.1 mg N-NO_2/l and then decreased.

Nitrification was satisfactory till the 30th day of the experiment. Afterwards there was an inhibition of nitrate increase in water followed by a rapid decrease (Fig. 2). At the same time nitrite levels increased considerably. No significant changes were observed as to the ammonia content.

Analyses of oxygen conditions in particular points of the model system revealed that partial denitrification was caused by suspended matter which had accumulated on the mechanical filter. Oxygen consumption by organic matter caused periodic decrease of oxygen content in the filter chamber to the level below 2 mg O_2/l and this triggered denitrification. On 42nd day of the experiment the filter was washed and this procedure stopped denitrification process, so that nitrite content decreased again while nitrates increased. Notwithstanding the observed denitrification water quality in the system was better (with respect to nitrite and nitrate content) than in the first stage of the studies. Maximal concentration of nitrites reached 0.17 mg/l, while

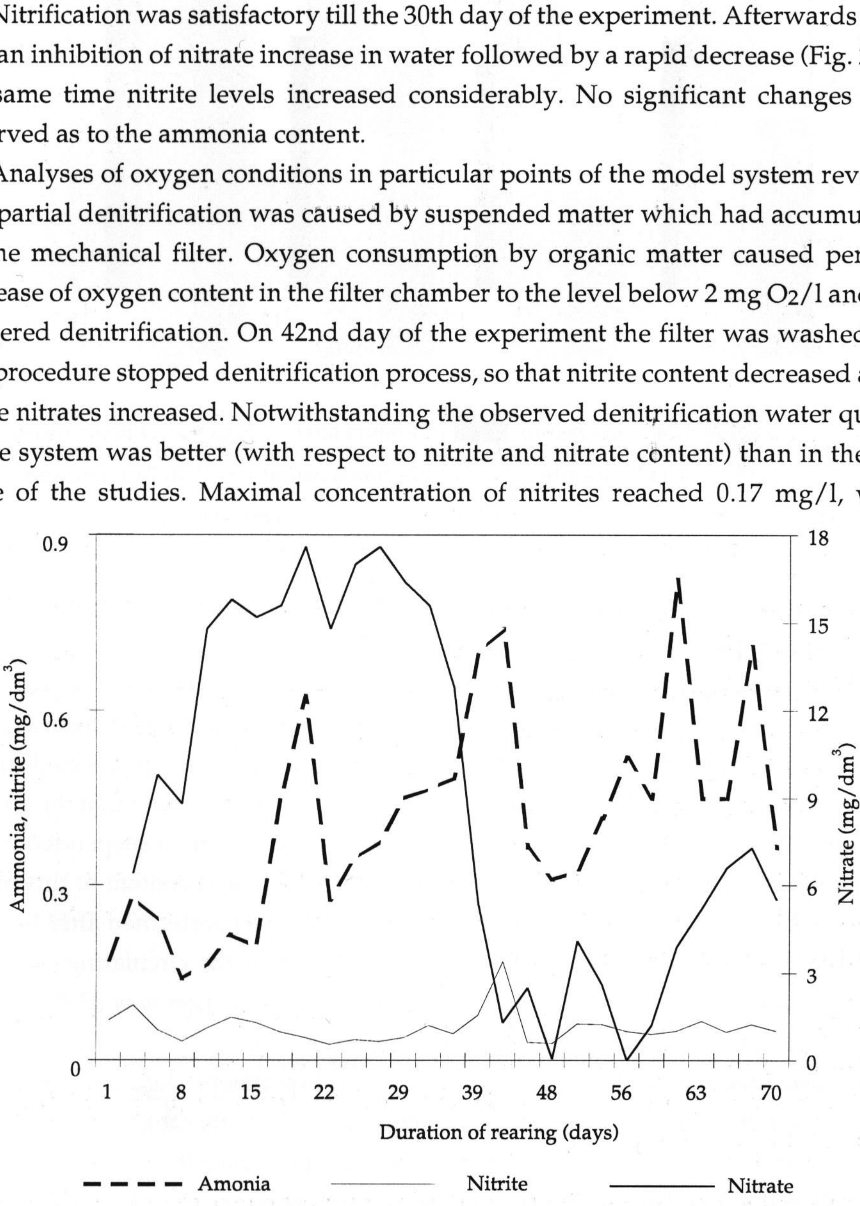

Fig. 2. Changes in amount of ammonia, nitrite and nitrate in the recirculation system

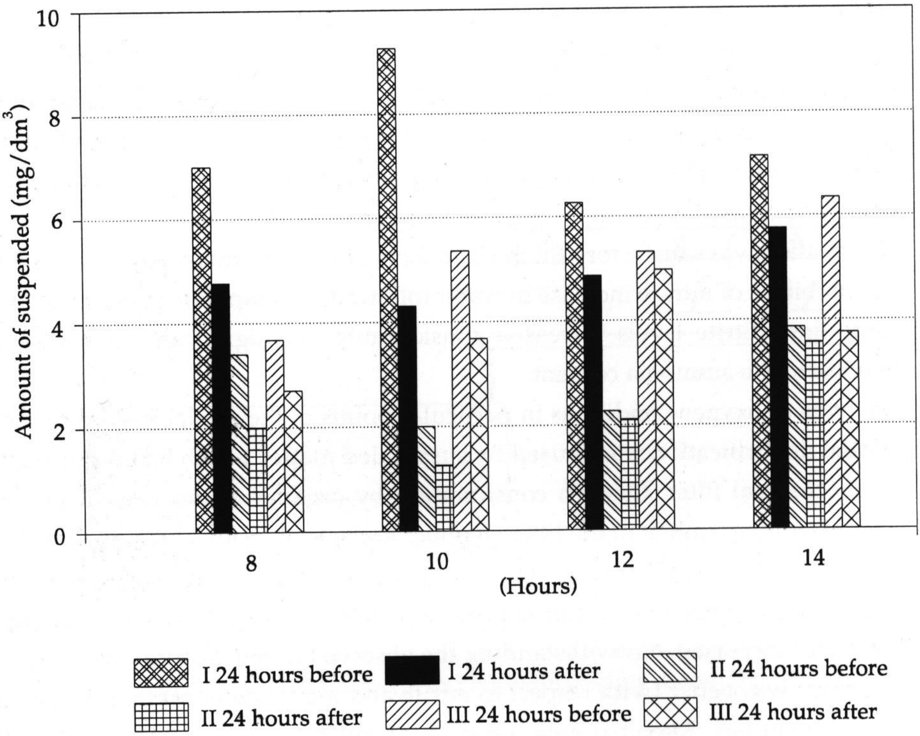

Fig. 3. Changes in amount of suspended solids after pressure mechanical filter application

maximal levels of ammonia were 0.6 - 0.9 mg/l at pH 6.5 - 7.0, so there was no danger for the fish (Alabaster 1982).

The mechanical filter was connected into the system on 26th day of the experiment. Before its connection the amount of suspended matter ranged from 25 to 30 mg/l. Two days after the filter began to operate analyses were performed of suspended matter content before and after the filter (Fig. 3). It was found that the amount of suspended matter decreased to less than 10 mg/l. Reduction of suspended matter changed from 47.16% to 12.28% (on the average per 24 h) and content of this matter showed a decreasing trend. Another series of analyses was performed after the filter had been washed. Total amount of suspended matter in the circulating water decreased to less than 4 mg/l (Fig. 4) and average daily reduction was 33.4%. Hence, filter washing had no significant effect on its effectiveness.

No fish losses were observed in course of the experiment. Also fish health was satisfactory. Rate of average weight increment of carp was higher than in the first stage of the studies (Fig. 5) probably due to better water quality (lower levels of ammonia and nitrites). On the other hand, rate of silver carp growth was slower (Fig. 6) due to worse feeding conditions for this fish (reduction of suspended matter content).

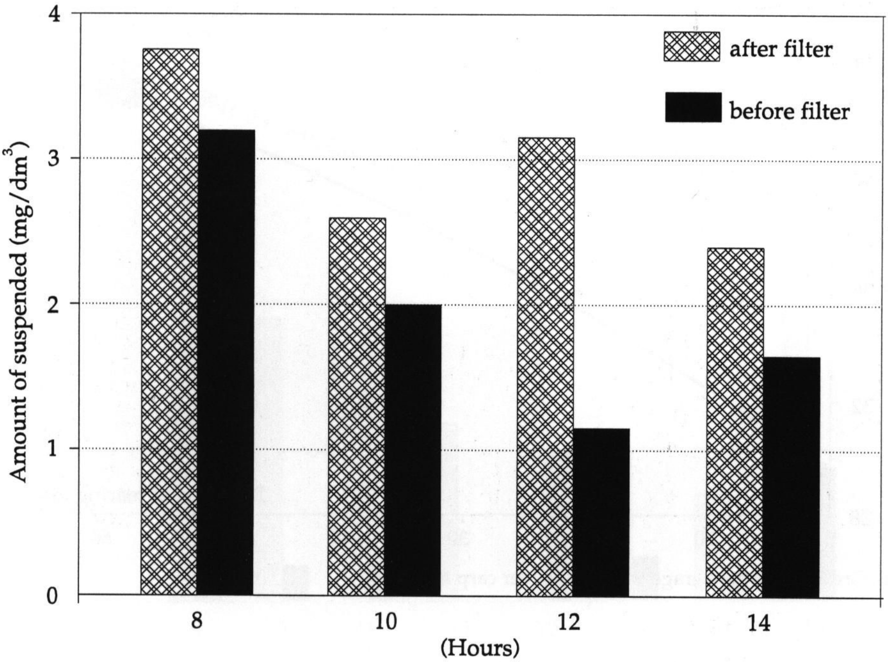

Fig. 4. Changes in amount of suspended solids in water after mechanical filter washing

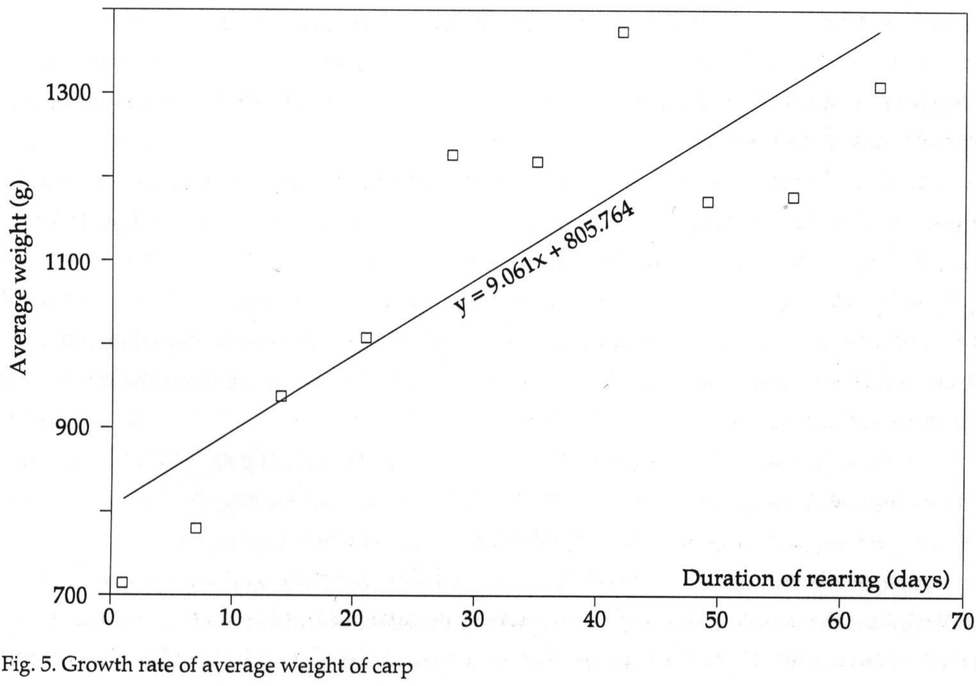

Fig. 5. Growth rate of average weight of carp

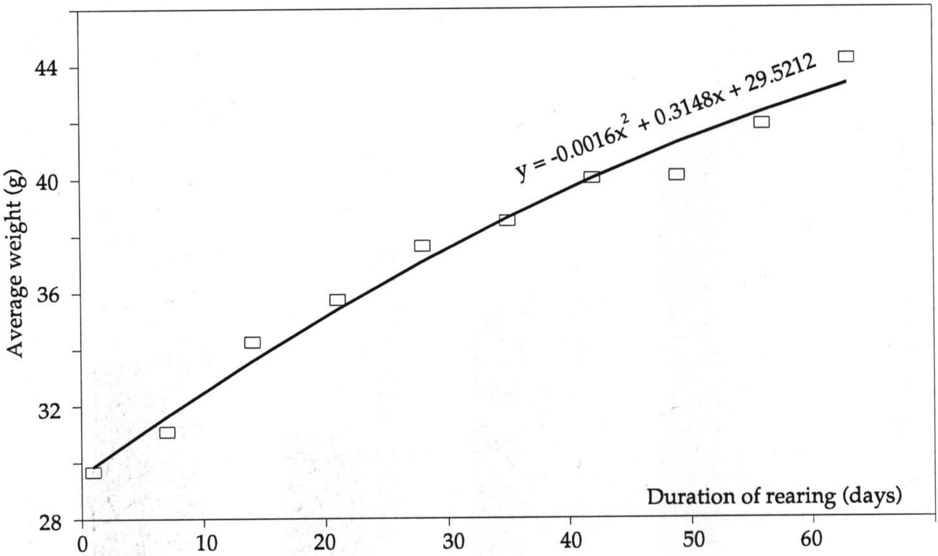

Fig. 6. Growth rate of average weight of silver carp fry

30 days after initiation of the experiment analyses were made three times on the amount of ammonia produced by the fish. Fig. 7 presents average data related to these analyses. Moreover, determinations were made on the percentage of sediment produced from the fish feeds (carp pellets) on a wet weight basis, and the amount of ammonia produced from the sediments (Fig. 8). It was found that wet weight of the sediments outflowing daily from the fish tank represented about 61% of the daily food ration weight. pH of water (6.5 - 7.0) was higher than in the first stage (6.0 - 6.5). Increase of pH value might have been caused by diatomite which constituted upper layer of the mechanical filter substrate.

Discussion on the effects of water purification and summary

The results obtained in course of the experiments were used to calculate average amounts of ammonia nitrogen excreted by the fish and produced from the metabolic products and undigested feed remnants:

- carp (average weight 1000 - 1100 g) - 1.83 mg $N\text{-}NH_4$/kg/h
- silver carp (average weight 37 - 38 g) - 6.97 mg $N\text{-}NH_4$/kg/h
- sediment (faeces and feed remnants) - 31.45 mg $N\text{-}NH_4$/kg/h

Assuming the amounts of ammonia excreted by carp and silver carp fry as average for the whole experiment, and taking into consideration the regression curves of the fish growth (Fig. 5 and 6) changes in daily ammonia production were calculated (Fig. 9). The obtained curves suggest that when absolute values are taken into account the fish appear to be the major ammonia „producer". Moreover, the curve of overall

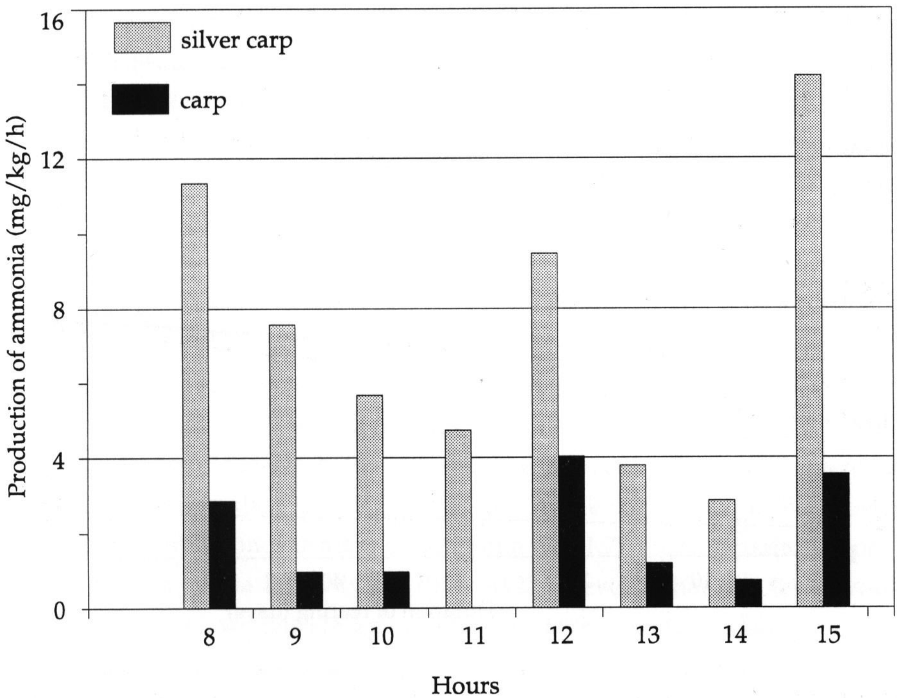

Fig. 7. Changes in amount of ammonia in water outflowing from the rearing tanks

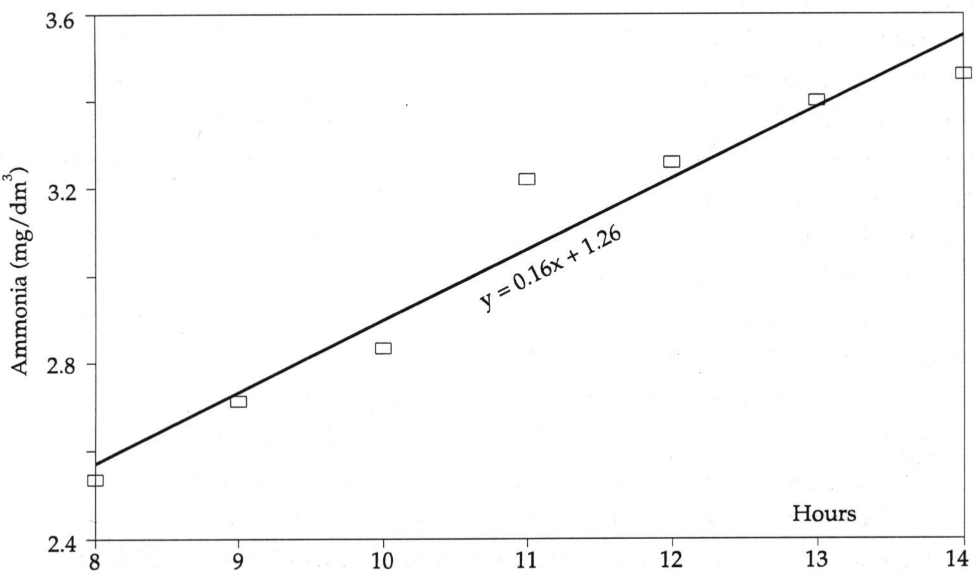

Fig. 8. Ammonium production by suspended matter

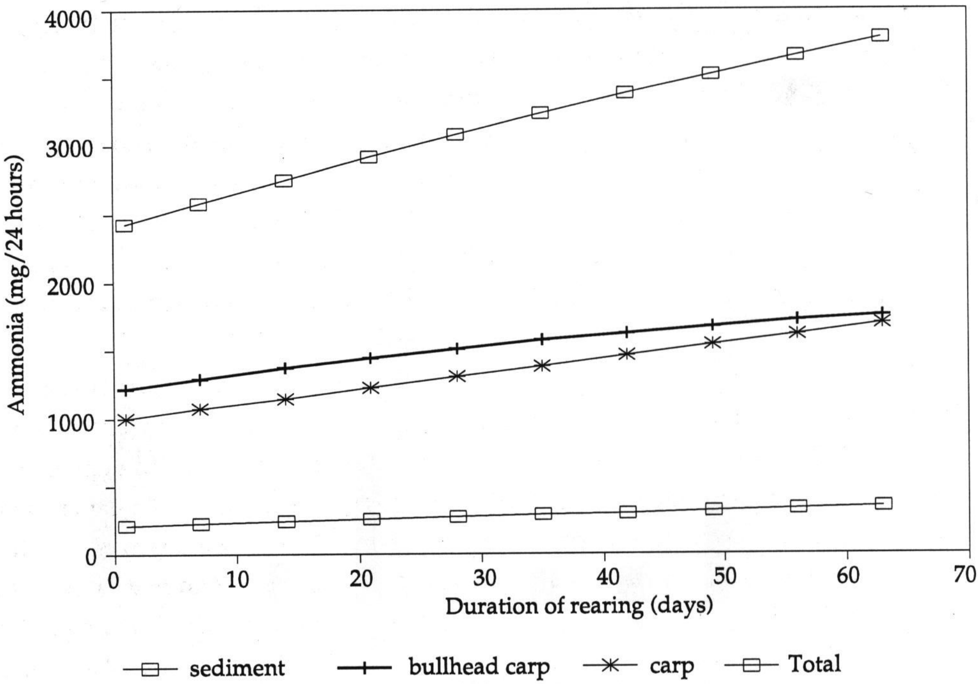

Fig. 9. Changes in ammonia daily production by fishes and suspended matter

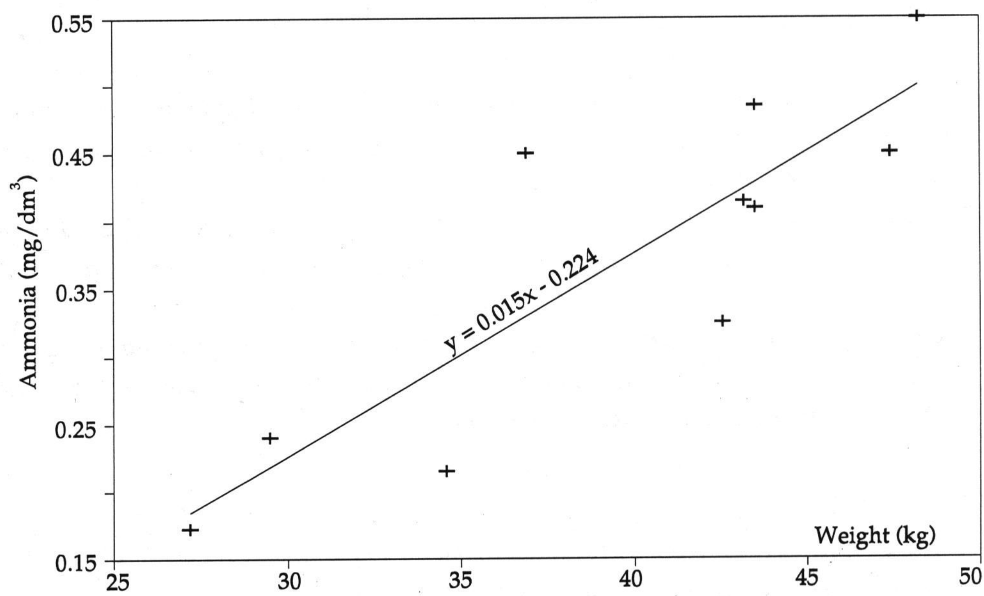

Fig. 10. Trend of ammonia growth in the recirculation system

ammonia production showed that in the final stage of the experiment the biological filter removed (through nitrification) 3783.6 mg of ammonia nitrogen daily i.e. about 10 mg $N\text{-}NH_4$ daily per 1 m^2 of active filter surface. In view of the fact that the observed levels of ammonia and nitrites were lower than the permissible ones (Spotte 1979) it may be stated that the biological filter did not attain its maximal effectiveness. Changes of ammonia and nitrite content (Fig. 2) reveal that only ammonia showed a somewhat increasing trend. Thus the first phase of the nitrification process (oxydation of ammonia to nitrites) was less intensive than the second one, and this phase determined the effectiveness of the biological filter.

Statistical analysis showed that changes of ammonia content were more related to the fish stock weight ($r = 0.7434$) than to the days of rearing ($r = 0.4072$). Hence further considerations were based on the dependence between ammonia content in the circulating water and the fish weight (Fig. 10). In the conditions of the experiment maximal permissible concentration of ammonia was 1.77 mg/l. Equation expressing the growth of ammonia levels ($y = 0.015x - 0.224$) reveals that this level would be attained at fish stock weight 118 kg i.e. after 369 days of rearing. Using the equation of overall and daily ammonia production (Fig. 9) ($y = 0.064x^2 + 26.007x + 2401.58$), it may be calculated that daily production of ammonia at that time would amount to 20709.88 mg i.e. 55.66 mg daily per 1 m^2 of active filter surface. This value should be regarded as theoretical maximal loading of the filter with ammonia per unit of the rotor surface.

Summing up the results it may be stated that:

1. This new technological line for fish fattening in a recirculation system ensures proper environmental conditions, as proved by satisfactory fish growth and lack of fish losses throughout the experiment.
2. Rotating biological filter characterized by relatively high effective surface (1328.8 m^2/m^3) can theoretically oxidize (by nitrification) 55.66 mg of ammonia per 1 m^2 per day.
3. Prototype mechanical filter proved to be sufficiently effective for removing the suspension in the conditions as described in this paper. It was also found that back filter washing did not decrease its effectiveness.

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STRESZCZENIE

BADANIA MODELOWE SYSTEMU RECYRKULACYJNEGO DO TUCZU RYB Z OBROTOWYM FILTREM BIOLOGICZNYM.

CZĘŚĆ II. BADANIA MODELOWE BIOLOGICZNEGO ZŁOŻA BĘBNOWEGO WSPÓŁPRACUJĄCEGO Z FILTREM MECHANICZNYM

Na podstawie wyników serii badań obrotowego filtra biologicznego dokonano zmiany wypełnienia rotora filtra, przez co uzyskano zwiększenie jego powierzchni względnej do 1328 m^2/m^3. Ponadto w trakcie eksperymentu włączono do linii technologicznej modelowego obiegu zamkniętego ciśnieniowy filtr mechaniczny.

Obsadę basenów modelowego obiegu zamkniętego stanowił narybek tołpygi białej (243 szt. ze średnią masą 29.6 g/szt.), oraz karp (28 szt. - średnia masa 714 g/szt.).

Zwiększenie efektywnej powierzchni względnej rotora filtra spowodowało wzrost efektywności utleniania amoniaku, a szczególnie II fazy nitryfikacji tzn. utleniania azotynów do azotanów, o czym świadczyły niższe niż w poprzednim etapie badań koncetracje amoniaku -0.9 mg $N\text{-}NH_4$ i azotynów -0,17 mg $N\text{-}NO_2$/l. Na podstawie statystycznej analizy eksperymentalnych danych stwierdzono, że badana konstrukcja filtru biologicznego przy maksymalnej obsadzie 118 kg ryb karpiowatych zapewnia utrzymanie bezpiecznych koncentracji amoniaku i azotynów tzn. posiada maksymalną zdolność utleniania amoniaku równą 55,66 mg/m^2/dobę. Zastosowanie filtra mechanicznego spowodowało redukcję ilości zawiesiny trudno opadającej z ok. 30 mg/l do 4 mg/l. Ponadto stwierdzono, że płukanie filtru odwrotnym strumieniem wody nie powoduje mieszania się warstw filtracyjnych i tym samym nie obniża się jego przepustowość i zdolność filtracyjna.

Adres Autora:

Doc. dr hab. Ryszard Kolman
Instytut Rybactwa Śródlądowego
10-957 Olsztyn-Kortowo
ul. Oczapowskiego 10