STUDIES AND RESEARCHES REGARDING THE BIOLOGICAL FILTRATION OF WATER IN A RECIRCULATING AQUACULTURE SYSTEM

Phd. Stud. Eng LAZA E.A.; Phd. Eng.CABA I.L.
INMA Timisoara Branch/ Romania
eveline_anda@yahoo.com

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ABSTRACT

It is necessary to maintain optimal water quality parameters for a proper operation of a recirculating aquaculture system for fish breeding. A biological filtration installation has to be performed so that to satisfy the system requirements on the conversion of ammonia to nitrite and then to nitrate, less toxic products for the fish population. The presence of ammonia and metabolites in water is a stress factor for concentrations higher than 0.05 mg/nitrogen ammonia (NH_3 - N) and this will be felt in the growth of fish and in their resistance to disease.

INTRODUCTION

The feasibility and efficiency of the activity of a recirculating growing aquaculture system depends on the extent to which an optimal correlation between the technological management, the carrying capacity and the water quality is ensured (Andrei S.G., Pop A., David E., Ştefanov C. 2014, Cristea V., Grecu I., Ceapă C.,2002, INMA Bucharest 2011, Ştefanov C. 2011).

The water quality of a recirculating aquaculture culture is critically determined by its concentration in dissolved oxygen, non-ionized ammoniacal nitrogen, nitrites and carbon dioxide. The level of concentration in nitrates, pH and alkalinity are also important parameters for assessing water quality (Andrei S.G., Pop A., David E., Ştefanov C. 2014, Bura M., 2002,INMA Bucharest 2011, Ştefanov C. 2011).

Biological filtration, in the broadest sense, includes any filtering technique that uses living organisms to remove a number of toxic compounds from the water. Biological filtration includes a variety of processes consisting of the use of plants or processes of nitrification, denitrification and aeration. For recirculating aquaculture systems, the nitrified filtration systems that allow the control of nitrogen compounds and, first of all, the removal of ammonia are of particular interest (Ştefanov C. 2011, INMA Bucharest 2011, Popa Paula, Neculai Patriche, Raluca Mocanu, Costel Sârb, 2001).

The main problems considered in establishing the operating principles of the nitrifying filters are: the kinetics of the nitrification process, the configuration of the nitrifying filters, the physico-chemical and biological parameters that influence their functioning (Andrei S.G., Pop A., David E., Ştefanov C. 2014, INMA Bucharest 2011, Ştefanov C. 2011.

The decomposition of nitrogen compounds is of particular importance in aquaculture because some of the decomposition products, mainly ammonia-NH_3 and nitrogen-NO_2, are toxic. To a lesser extent, NO_3 nitrates are toxic when, by accumulation, they reach high concentrations. In recirculating systems, the residual organic substance (non-consuming food, manure) is decomposed by heterotrophic bacteria into simpler organic compounds, the final product of this process being ammonia, an unstable compound that turns into ammonia. In a first phase, ammonia is oxidized by autotrophic bacteria in nitrites (NO_2). In the second phase, under the action of other types of autotrophic bacteria, the nitrites are transformed by oxidation into nitrates (NO_3) which become toxic when they accumulate in too large a quantity(Biliard R., 2002, Ştefanov C. 2011, INMA Bucharest 2011,Andrei S.G., Pop A., David E., Ştefanov C. 2014).

The energy source of heterotrophic bacteria is represented by the carbon compounds and for the autotrophs the inorganic nitrogen

In their metabolic activity, both heterotrophs and autotrophs use oxygen, but the growth rate of heterotrophic bacteria is appreciably higher. Under these conditions, the nitrogen cycle in the same nitrification filter leads to competition for the growth space between heterotrophic and autotrophic bacteria. The filtering agent is a solid material introduced into the filter to provide growth support for nitrifying bacteria. (Cristea V., Ceapă C., Rauta M., 1998, Andrei S.G., Pop A., David E., Ştefanov C. 2014, Rakocy J., Losordo M.T., Masser P.M., 1999,).

As for their nature, there are several types of filtering agents used in the nitrification process. The usual filtering agents are represented by various types of mineral aggregate (sand, gravel, broken stone, limestone, etc.) as well as by different plastic structures. The type of filtering agent is chosen according to certain criteria, the most important being the granulosity, the specific surface, the cost and the specific weight. The mineral aggregate is not recommended as a filter medium in the case of drum biofilters, as well as those that require frequent manipulations caused by the washing operations (Rakocy I., Losordo M.T., Masser P.M., 1999,Andrei S.G., Pop A., David E., Ştefanov C. 2014, INMA Bucharest 2011, Ştefanov C. 2011).

The use of the mineral aggregate as a filter medium is recommended, first of all, due to the generally low cost. Compared to mineral filtering agents, plastics offer some technological advantages, namely reduced specific weight and porosity, respectively greater specific surface area. Plastic structures are more expensive and have no buffering capacity, but the advantages mentioned are important, justifying their widespread use in aquaculture. To ensure proper use of the filter during the operation of the filter, plastic filter agents should not be exposed to sunlight (Cristea V., Ceapă C., Rauta M., 1998, 1999, Andrei S.G., Pop A., David E., Ştefanov C. 2014, INMA Bucharest 2011, Ştefanov C. 2011).

MATERIAL AND METHOD

The nature of the filter medium and its granulosity are chosen, differentiated for each type of filter, according to their mode of operation.

The specific active surface represents the surface of the filtering agent relative to the volume unit. From a constructive and functional point of view, for a nitrifying filter, the specific surface is an essential parameter as it determines the degree of development of the biological film. The specific surface of a filtering agent depends on its granulosity characteristics, the most important being the porosity and the diameter of the constituent particles. The filter media represented by filter agents with reduced porosity, respectively small diameters of the granules, provide larger specific surfaces; Under these conditions, more bacteria can develop per unit volume of the filter medium and, consequently, the rate of ammonia removal increases. However, the diameter of the granules of the filter medium cannot be reduced below a certain value to limit the loss of load and the rate of clogging.

Fig.1 Location of the biological filter at the place of experimentation

The experimentation used metrological devices and measuring devices, adjusted and calibrated accordingly. For the dimensional checks of the main subassemblies of the biological water filtration equipment, as well as for the determination of mechanical, thermal, hydraulic and chemical parameters, fixed or portable measuring instruments, presented in table no. 1:

Table 1

Measuring instruments

No.	Name of the instrument or device	Measuring range	Measurement uncertainty / Error tolerated
1	Colorimeter for complete laboratory analysis - C 200	with 36 parameters	
2	Ammonium Kit (LR), for 300 tests	0.00-3.00 mg/l	±0.04 mg/l ±4% from reading
3	Ammonium kit (MR), for 300 tests	0.00-9.99 mg/l	±0.05 mg/l ±5% from reading
4	Nitrate kit, for 300 tests	0.0-30.0 mg/l	±0.5 mg/l ±10% from reading
5	Nitrite kit,for 300 tests	0-150 mg/l	±4 mg/l ±4% from reading
6	Graded cylinder, A, with beak, with brown marking	100 ml,	
7	Graduated Pipette, A, with dimension, with brown marking,	2/0,1 ml	
8	Graduated Pipette, A, with dimension, with brown marking	5/0,1 ml	
9	Type A balloon, with plastic stopper, NS 7/16	5 ml	
10	Type A balloon, with plastic stopper, NS 7/16	10 ml	
11	Test tube with gradation and plastic stopper	10 ml	
12	Test tube with gradation and plastic	25 ml/0.5 ml	

No.	Name of the instrument or device	Measuring range	Measurement uncertainty / Error tolerated
	stopper		
13	Analytical laboratory funnel	diam. 65 mm	
14	Chronometer	60s; 30min	uncrt. 0,2s
15	Digital thermometer with laser type UNITEST 94009, series 021117918	- 50 ^oC … 0 ^oC 0 ^oC … +200 ^oC +200 ^oC …+1.333 ^oC	± 2 % ± 1,5 % ± 1 %
16	Technical thermometer with massive capillary STAS 8374 / 1-69	- 20 … +30 ^oC	± 0,2 ^oC
17	Digital camera	-	-
18	Electrochemical multimeter C863		
	pH	-2...+16 pH	0,001...0,1 pH
	conductivity	0...2000 mS/cm	0,001 mS/cm
	dissolved oxygen	0...60 mg/l	0,001 mg/l sau ± 1 %
	temperature	-30...+130 ^oC	± 0,1 ^oC
19	Thermo-Anemo-Manometer MP 200		
	Pressure	0 la ±1000 mmH_2O	±0,5%
	Speed with Pitot tube	4-30 m/s	±3 % ±0,1 m/s
		31-100 m/s	±3 % ±0,3 m/s
	Flow with Pitot tube	0-65.000 m^3/h	±3 % ±10 m3/h

For the tests under load of the biological filter was used waste water from a recirculating aquaculture system, the total volume of water being 62 m3. Before being put into operation for experimentation, the filter element was introduced into the two cavities of the biological filter, and the distributors were connected to air and oxygen sources. The biological factor of the filter element (Nitrosomonas) was seeded with approx. two weeks before the beginning of the experiments.

The working capacity was expressed by the flow of filtered water in close connection with the qualitative parameters of the biological filtration, so that the biological filter fulfills in good conditions the technological functions it has within the recirculating aquaculture system.

Further the start and operation of the biological filter was made by opening the waste water and air inlet valves as well as the filtered water outlet faucet.

The reservoir purge faucet and the oxygen intake faucet remained closed during normal biological filter operation.

Fig.2 Electrochemical multimeter C863

Fig.3 Colorimeter for complete laboratory analysis - C 200

The qualitative parameters of biological filtration were obtained by comparing the results of the physico-chemical analyzes of the water from the samples taken at the inlet and at the outlet of the biological filter.

To be edifying, these samples were taken after the filter was operated in the same temperature and flow regime, with water entering with a relatively constant degree of pollution. The sample from the filter exit was taken after the water passage time, previously determined, so that it is as close as possible to the sample of the sample taken at the inlet.

The determination of the ammonium, nitrate and nitrite content of each water sample was done using the colorimetric for complete laboratory analysis - C 200, with the corresponding reagents.

RESULTS AND DISCUSIONS

As we know the main measured parameters, which have relevance in the functioning of the biological filter are: the pH, as well as the water concentrations of oxygen, ammonia, nitrates, nitrites and ammonia.

Following the experiments of the biological filter, physico-chemical parameters of the water were determined at the water supply of the biological filter, the results being shown in table number 2.

Table 2

Physico-chemical parameters of water at the discharge of the biological filter

No	Physico-chemical parameter	M.u.	Medium values
1.	pH	upH	7,6
2.	Oxygen	mg/l	4,1
3.	Ammonia (NH^{+}_{3})	mg/l	0,05
4.	Nitrates (NO^{-}_{3})	mg/l	5,5
5.	Nitrites (NO^{-}_{2})	mg/l	0,3
6.	Ammonium (NH^{+}_{4})	mg/l	0,5

The determined physico-chemical parameters have normal values for the water in the recirculating aquaculture systems, the concentration of the nitrogen compounds approaching the maximum allowed limit.

Analyzing the samples taken from the filtered water upon its discharge from the biological filter and determining its physico-chemical parameters, the following average values were obtained, which were noted in table 3.

Table 3

Physico-chemical parameters of water at the supply of the biological

No	Physico-chemical parameter	M.u.	Medium values
1.	pH	upH	7,6
2.	Oxygen	mg/l	6,2
3.	Ammonia (NH^+_3)	mg/l	0,0
4.	Nitrates (NO^-_3)	mg/l	0,1
5.	Nitrites (NO^-_2)	mg/l	0,02
6.	Ammonium (NH^+_4)	mg/l	0,0

CONCLUSIONS

Comparing the results recorded in the tables no. 2 and 3, of the samples taken from the inlet and outlet of the biological filter, it is found that the nitrification process takes place, and the biological filtration is efficient and reduces the concentration of nitrogen compounds to allowable limits, not dangerous for fish.

Following the experiments on the biological filter it was found that the average duration of action of the bacteria on the water in the circuit, is equivalent to the duration of residence in the biological filter and lasts about 6 minutes. If after this time the nitrification process is not complete, it turns out that the number of bacteria must be increased, by increasing the unfolded surface of the filter element, or the residence time of the water in the biological filter must be increased, which implies a reduction of the working flow. If the desired result is not obtained under these conditions, the volume of the filter element must be increased by adding a new filter module. Also, the process of nitrification is done by consuming oxygen, so it is important to ensure a good aeration of the water. In case of need it is required to directly blown oxygen in the basin of the biological filter.

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