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Fish Farm Recirculating Water Treatment by Reactors with Fixed Biocenosis

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Abstract: Reactors with fixed biocenosis are most commonly applied for fish farm recirculating water treatment, as they have a number of advantages over other biological purification plants. In actual practice, inefficient plants which generally operate in a single-stage mode are often used. Finer treatment of fish farm recirculating water with removal of organic and nitrogen-containing contaminants can be achieved by a multi-stage biological process. Comparative studies of multi-stage treatment of fish farm recirculating water by reactors with fixed biocenosis were conducted in order to choose the optimal process flow scheme. The study results determine optimal process flow schemes for fish farm recirculating water treatment in such bioreactors as well as parameters for their operation in the course of bio-oxydation of organic contaminants and ammonium salts and denitrification. The best results were achieved when applying three-stage biological treatment of fish farm recirculating water where the oxidizer is configured as a percolating filter and the nitrification filter and the denitrification filter are accomplished in the form of flooded bioreactors. Besides, the oxidizer and the nitrification filter are placed successively in the main water flux to be treated whereas the denitrification filter is installed in a separate zone. The obtained results allow to define reactor volumes for carrying out of nitrification and denitrification in the course of fish farm recirculating water treatment.

Key words: Recirculating water treatment · Fish farming systems · Reactors with fixed biocenosis · Biological water treatment · Biofilters-oxidizers · Nitrification filter · Denitrification filter

INTRODUCTION

Fish farming systems with recirculating water supply (fish farm tanks, aquaria, public aquatic complexes, oceanaria etc.) are becoming more widespread. The necessary water quality indices in such fish farming systems are provided by a large number of water changes in tanks, efficient water purification and conditioning (measuring indices: pH, temperature, dissolved oxygen). Water withdrawn from fish farm tanks for treatment has relatively low contamination concentration which is limited by maximum allowable concentration (MAC) values for definite fish species [1-4].

One of the main methods used in such systems for recirculating water treatment is biological method applied in reactors with free-swimming or fixed biocenosis (aerotanks and biofilters) [1, 6, 7]. Besides, reactor with fixed biocenosis find the most common application. These reactors as applied to the specified systems have advantage of creating high biomass concentrations in the biological treatment unit and, consequently, intensifying the treatment process, reducing volumes of biological treatment units, providing conditions for stratification of various microorganism species in the direction of fluid travel etc.

Finer treatment of fish farm recirculating water with removal of organic and nitrogen-containing contaminants can be achieved in plastic-packed bioreactors during the execution of a multi-stage biological process [5-8].

MATERIALS AND METHODS

The study of various schemes of recirculating water treatment (Fig. 1) was conducted in semi-production systems (for breeding of planting material and marketable carp) with efficiency 0.6–1.5 m^3/h. Three different plants

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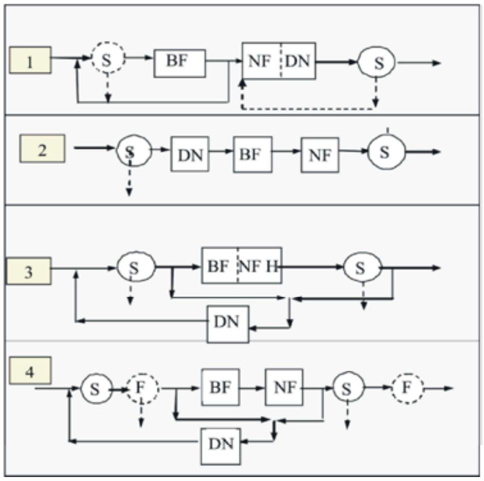

Fig. 1: Bioreactors process flow schemes: S – clarifier; BF – biofilter; NF – nitrification biofilter; DN – denitrification biofilter; F – filter

with recirculating water supply were used in the study. The plants comprised standard and nonstandard fish-farming tanks, facilities for biological and mechanical treatment, temperature regulator, aerator. The plants distinguished by volumes of treatment assemblies and fish-farming tanks, mechanical treatment facility types, mutual arrangement and relation of biological treatment assemblies [8].

The Main Part: Comparative study of operation schemes of unit for fish-farm recirculating water biological treatment was carried out in order to determine the most optimal scheme. The optimality criterion was minimal total facility volume which ensures the required quality of purified water according to normalized fish farming indices [8-11].

The first scheme (Fig. 1) provides two-stage biological treatment of recirculating water in a percolating filter and a flooded biofilter upper zone of the latter acted as a nitrification filter whereas the lower zone acted as a denitrification filter. This scheme included a primary mechanical treatment assembly as it was supposed that water clarification would occur in the flooded part of the biological treatment unit and, finally, in the secondary clarifier. Initial suspended solid materials entered the denitrification zone were the source for carbonaceous organic matters which intensified the process. Exclusion of the primary clarifier reduced the total volume of the treatment unit. The study of the plant operation according to this scheme showed that a significant amount of undissolved impurities was sorbed in the 1st stage of the biofilter which reduced its efficiency in dissolved organic matter removal and led to excessive biomass buildup. The latter fact required to increase the distance between cloths of filter bed (so that it would not be blocked by slit), hence, the specific surface area of the bed in the facility was reduced. Finally, that required to increase the facility volume. Sequential arrangement of the denitrification filter after the nitrification filter also proved to be inefficient for this scheme. The nitrification process in the intermediate region between these zones was significantly limited by low concentration of dissolved oxygen and so it was substantially an inactive region. Extension of the nitrification zone resulted in reduction of the denitrification filter capacity. Consequently, the plant operation according to the first scheme was proved to provide the most inefficient water purification from ammonium compounds and nitrates as compared with other tested schemes (given equal total volume of the nitrification filter and the denitrification filter and the load applied on them).

The objective of the study of various schemes for recirculating water treatment included comparison of the plant capacity and efficiency when the denitrification filter was placed before and after the biofilter-oxydizer and the nitrification filter [1, 3, 5]. Scheme 2 (Fig. 1) provided a three-stage biological treatment of recirculating water with the denitrification filter placed before the oxidizer. According to this scheme, the denitrification filter received organic substrate in the form of "new" contaminants with influent water from fish tanks and nitrates – with recirculating water. The scheme was completed by a primary clarifier in order to reduce the possibility of the denitrification filter silting by suspended solids. The study of this scheme showed that the plant operation in this case is, to some extent, more efficient as compared with the scheme 1 (Fig. 1). Water without oxygen exited the denitrification filter and was oxygenated in the percolating biofilter-oxydizer where nitrogen and carbon dioxide ware also desorbed. This scheme required to increase the denitrification filter volume in order to enhance nitrate purification efficiency as the filter upper zone essentially functioned as an oxidizer due to high dissolved oxygen concentration in the water exiting fish tanks. While the biological treatment unit had equal volumes in schemes 1 and 2 (Fig. 1), the efficiency of removal of ammonium nitrogen was higher in the second scheme and the efficiency of nitrate removal was higher in the first scheme. These both schemes appeared to be not efficient enough [11].

The inclusion of a mechanical treatment assembly in the scheme has a positive effect, thereby organic contaminant and ammonium nitrogen load on the biological treatment unit was reduced and the unit efficiency was increased. Consequently, biomass buildup in the biofilter-oxidizer was reduced enabling to increase the specific surface area of the filter bed. Total volume of the treatment unit due to the volumes of the primary clarifier and the additional zone of the denitrification filter increased by 1.5 times in comparison with Scheme 1 (Fig. 1).

In Scheme 3 (Fig. 1) the main water flow from fish farm vessels was directed after the primary clarifier to the single-stage low-rate biofilter operated as an oxidizer with simultaneous nitrification. A part of the clarified water and a part of the biologically treated water flow were directed to a separate denitrification filter after which they returned to the inlet of the treatment unit. Position of the denitrification filter on the bypass flow allowed, on the one hand, controlling the relation between the carbonaceous substrate flow rate and the nitrate flow rate which were entering the denitrification filter and, on the other hand, providing the required stay period of the fluid in the denitrification filter and the appropriate purification efficiency. The results of the plant operation according to this scheme showed that while the volumes of the treatment unit in Schemes 1 and 3 (Fig. 1) as well as the loads were equal, the quality of water treated according to Scheme 3 (Fig. 1) was higher in all the indices. The efficiency of nitrate removal according to this Scheme was higher than that according to Scheme 2 (Fig. 1), with the load being equal and the volume of the treatment unit was less. Only 20% of the recirculating water flow rate passed through the denitrification filter, consequently, the stay period of the fluid in it was increased by 5 times (in comparison with the variants when the denitrification filter was placed in the main flow). Oxidation zones in the denitrification filter substantially dissapeared and the efficiency of nitrate removal was higher.

The optimal indices were obtained when Scheme 4 (Fig. 1) was applied, which differed from Scheme 3 (Fig. 1) by the configuration of additional clarifying filters and separation of oxidizer from nitrification filter. The denitrification filter, as in the previous Scheme, was installed in a facility separated from the main flow where the mix of the influent water and the purified water entered [8-11].

Depending on the load on the 1st stage biofilter, the nitrification process can start and take place if the degree of removal of carbonaceous organic contaminants is sufficiently high. Ammonium compounds are substantially removed by the 2nd stage of the bioreactor (the nitrification filter) (Fig. 2).

The process free nitrogen regeneration from nitrates tooks place in the denitrification biofilter which is accompanied by reduction of NO^-_3 concentration in water, reduction of chemical oxygen demand (COD) and

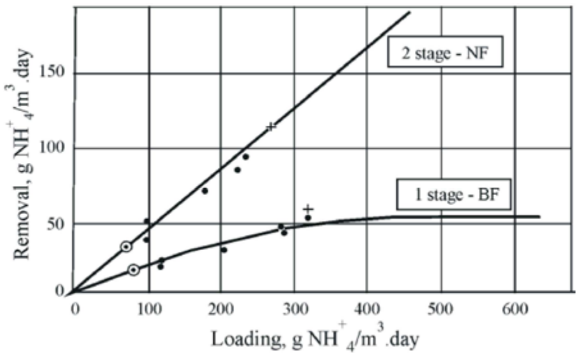

Fig. 2: Interrelation between the load and NH^+_4 removal in the biofilter stages 1 stage – biofilter-oxidizer (BF); 2 – nitrification filter (NF)

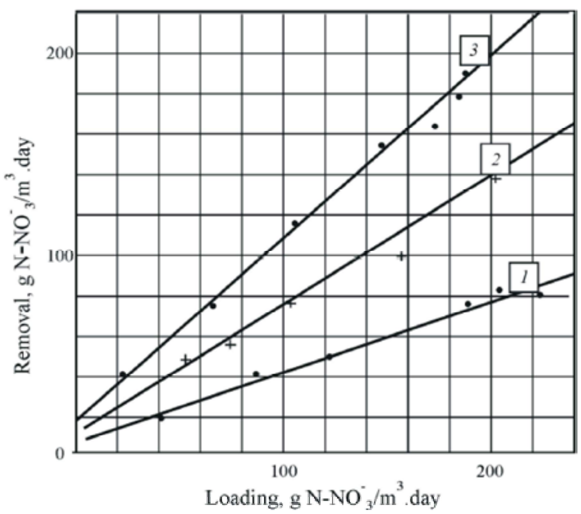

Fig. 3: Denitrification biofilter capacity according to the load and water treatment duration: *1*– 0.33 hour; *2* – 0.71 hour; *3* – 1.75 hour

biological oxygen demand (BOD), simultaneously, alkalinity increases (3.75 g of $CCaCO_3$ per 1g $N\text{-}NO^-_3$). The data on the denitrification filter efficiency of removal of nitrate nitrogen depending on the load applied on it and duration of water treatment are shown on Fig. 3.

The obtained results (Fig. 2, 3) enable defining the reactor volumes for execution of nitrification and denitrification processes in the course of fish farm recirculating water treatment according to flow rate and contaminant concentration in the water inflow [11, 12].

CONCLUSIONS

The article considers various process flow schemes for biological treatment of fish farm recirculating water with application of reactors with fixed biocenosis in order to perform organic contaminant oxidation, nitrification and denitrification. The best results are achieved when applying three-stage biological treatment of fish farm recirculating water where the oxidizer is configured as a percolating filter and the nitrification filter and the denitrification filter are accomplished in the form of flooded bioreactors.

Ammonium compounds are substantially removed by the 2^{nd} stage of the bioreactor (the nitrification filter). The process of free nitrogen nitrate regeneration in the denitrification biofilter requires adding carbonaceous organics the source of which can be untreated water drained from fish farming tanks. The obtained results enable defining the reactor volumes for execution of nitrification and denitrification processes in the course of fish farm recirculating water treatment according to flow rate and contaminant concentration in the water inflow. When modeling a water circulation system on the basis of the principles of systems analysis of the facility, it is necessary to consider the combination of all simultaneous processes of contaminant transformation in treatment units and removal of sediments, built-up biomass and evolved secondary contaminants.

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