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PURIFICATION OF RAS CIRCULATING WATER FROM PHOSPHOROUS COMPOUNDS

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The need to control the phosphorus concentration in the RAS circulating water is connected with the metabolism of fish that secrete phosphorus compounds in dissolved and undissolved form. The analysis of the phosphorus-containing contaminants formation in the RAS circulating water has been carried out. The expediency of using higher water plants for removing dissolved phosphorus compounds from water simultaneously with its purification from ammonium nitrogen, nitrites and nitrates has been grounded. Based on the chemical analysis of the composition of plants used as purifying agents as well as their biomass doubling time, prediction has been made of the specific phosphate assimilation rate in the phyto-reactor. The proposed balance diagram of phosphorus compounds transformation in the process of complex biological purification makes it possible to estimate the purification potential of individual hydrobionts for this contamination component.

Key words: RAS, water purification, removal of phosphorus compounds.

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INTRODUCTION

When growing fish in installations with closed water supply, it is especially important to efficiently purify circulating water from contaminants that include the products of fish metabolism and unutilized feed residues. Restoration of the water quality to the parameter values which characterized it at the time of its supply to the fish-breeding basin makes it possible to reuse it, thus realizing the main advantages of RAS. The RAS technologies and structures used for purification of circulating water are undergoing some changes related to the scientific and technological progress, to deeper study of the effect of individual abiotic factors on fish growth rate, as well as to the strict requirements of environmental legislation regarding the discharge of insufficiently treated sewage into water bodies. The instances of such changes can be seen in the structural development of filters for mechanical treatment and the facilities for dehydration of sediments, the justification of the expediency of including denitrifying agents in the biological treatment unit. Also much attention has recently been paid to the process of removing phosphorous compounds from RAS water, which is associated not only with the task of creating favorable conditions for fish production, but also with the negative consequences of the phosphorus-containing water discharge into natural water bodies (Martins et al. 2010). The need to purify circulating water from phosphorus compounds is due to their rather high content in fish metabolism products, especially in feces, and also to the ability to accumulate in water in a dissolved form. Before the concentration of phosphorus compounds did not reach the values that were dangerous to fish, which was ensured by using make-up water within the range of 20-30% of the basin volume per day. While the efficiency of nitrogen compounds removal from water due to biofilters-denitrifiers increased, the share of recycled water rose to 95% and even higher. At the same time, there was a tendency for phosphates to accumulate in the circulating water. These factors justify the necessity of searching for effective methods of removing phosphorus compounds from water for successful fish farming in RAS (Heinen 1996, Kamstra 2001, Rodehutscord 1994). The negative effect of phosphates is especially pronounced at the early stages of fish development (Martins 2009), besides, the increased content of phosphates in the RAS water leads to the fish growth rate slowing down, to the decrease in the feed digestion efficiency.

MATERIALS AND METHODS

To predict the load on the wastewater treatment plants as to phosphorous compounds, use has been made of the data on fish metabolism characteristics and the composition of feeds used in aquaculture.

The basic amount of phosphorus compounds entering the basin water is in a undissolved form – from 80% (Bodvin 1996) to 80-90% (Asgård, Shearer 1997). Proceeding from the analytical calculations of the potential load on the water treatment unit for trout farming (Bregnballe 2015), it can be assumed that the concentration of dissolved phosphorus compounds in RAS contaminated water varies within 0.9-2 mg/dm^3. Depending on the effectiveness of insoluble contaminants removal in mechanical purification facilities, the time spent by contaminated water in sedimentation tanks and other factors, the concentration of dissolved phosphorus can increase by 20% due to the dissolution of solid phosphorus compounds in water. The rest of the undissolved phosphorus will be removed from the system during the mechanical purification phase. The assimilation potential of aquatic plants relative to phosphorus compounds has been estimated proceeding from the amount of phosphorus in the cells of individual macrophyte species. Preliminary studies on the removal of nitrogen compounds have confirmed the expediency of using duckweed species (Lemnoideae) for circulating water purification.

In phyto-reactors purifying contaminated RAS water ammonium nitrogen and nitrates were extensively removed by weeds (Sabliy 2016). The best adaptability to the cultivation in RAS water and the highest growth rates have been demonstrated by *Lemna minor* Linnaeus, 1753 and *Wolffia arrhiza* (L.) Horkel ex Wimm, 1857. Therefore conclusions regarding the amount of assimilated phosphorus can be made based on the chemical composition of these plants and the content of phosphorus in them. According to the data presented (Mkandawire 2007), the content of nitrogen and phosphorus in the green weight is 60,000 and 5,000-14,000 mg/kg, respectively, and is significantly dependent on the availability of nutrients in the water. Maximum phosphorus levels of 10-14 mg/kg dry weight can be achieved at a phosphorus concentration in water of 1-3 mg/dm^3 (Leng 1995). Given that the amount of dry matter in the green weight of the plant can be 6-8% (Leng 1995), the phosphorus content in 1 kg duckweed dry weight should be in the range of 0.8-1.2 mg/kg. In phyto-reactors purifying RAS circulating water the time of cultivated weeds biomass doubling makes 2-4 days. Thus, it can be assumed that if the maximum weed growth rates are ensured, the potential of duckweed in phosphorous removal can amount to about 0.2 mg P per 1 kg of weed green weight per day. To ensure the removal of phosphorus at its concentration in contaminated water of 0.5-2 mg/dm^3, the total nitrogen content should be in the range of 4-16 mg/dm^3, which complies on the whole with the RAS contaminated water characteristics.

RESULTS AND DISCUSSION

Despite certain beneficial effects of phosphorous removal by using reagent methods (Rishel, 2006) it has not become wide-spread in aquaculture. Restrictions on the use of reagent methods are also connected with the high cost of flocculants. The necessity to properly utilize a substantial amount of waste products formed in the process of phosphorous chemical deposition, the danger of fish poisoning by reagent residual concentration getting into aquatic system promote the use of biological purification methods. Modern technologies of sewage purification are characterized by a great number of circulation flows and high energy intensity, which can significantly affect the cost of RAS water treatment. That is why their use for phosphorous compounds removal as a separate process in water quality restoration is not expedient. The results of studies on phosphates removal under conventional RAS water purification system by means of nitrification – denitrification process confirmed the possibility of phosphorous compounds accumulation by biological filter microbial community. However, it was not possible to achieve a high effect of phosphate removal from water. The reasons for this are the possibility of rapid release of the deposited phosphorus by microorganism cells, relatively low rates and volumes of phosphorus accumulation and the sensitivity of polyphosphate accumulating organisms (PAO) to changes in environmental parameters, the competitive relationships between individual groups of bacteria that make up the biofilm. It should also be noted that the undigested phosphorous which is a valuable nutrient contained in the feed turns practically into waste as a result of this biotechnology.

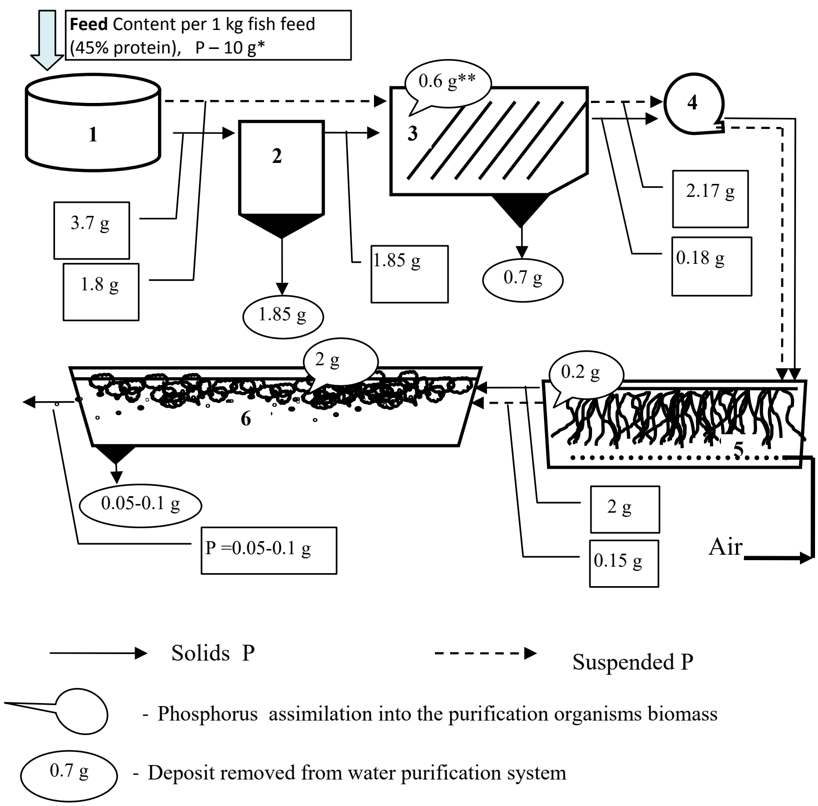
A more efficient way of purifying RAS circulating water from phosphorous compounds is their transformation into the biomass of organisms that can be used for feeding fish. The analysis of natural reservoir self-purification leads to the conclusion that phosphorous compounds transformation is performed mainly by plants. In the RAS closed circuit acceptable conditions are created for the realization of the purification potential of many hydrobionts, especially the higher aquatic plants. The main reason for this is the composition of the circulating water contaminants which fully meets the plants needs in nutrients. Unlike weeds which could also be effective purifying agents, when cultivating plants, there are no problems with keeping them in the reactor and separating them from the culture medium. The expediency of using plants for restoring water quality is well-grounded by higher effectiveness of nitrogen compounds removal from water compared to nitrobacteria. Cultivating plants which have nutritive value for fish in a phyto-reactor does not cause the problem of utilizing the purifying organism biomass because its use as an extra nutrition ensures practically non-waste production. In such case phosphorous assimilated by plants together with nitrogen are transformed into compounds which are available to fish, this enables more effective use of feeds and better phosphorous compounds removal from water.

Proceeding from the potential phosphorous load on the RAS water purification unit (Bregnballe 2015), the theoretical coefficients of molluscs biomass growth (Crab et al. 2007) and the information on the duckweed chemical composition (Leng 1995, Mkandawire 2007) we have developed a schematic diagram of phosphorous compounds transformation, mollusks, higher aquatic plants and periphyton organisms .participating in the process.

As can be seen from the scheme, most of the dissolved phosphates are transformed by plants into their own biomass and in this form they become available to fish as an additional feed. The phosphorus compounds found in undissolved contaminants are partially assimilated by mollusks, their biomass gain being also used as fish feed. Thus, when using this technology, an essential removal of dissolved phosphates from water is provided, and an opportunity is created for transforming the undigested phosphorus into plant and molluscs biomass available to fish.

CONCLUSION

The quantitative and qualitative composition of the contaminants in the RAS circulating water makes it possible to effectively use aquatic plants to remove dissolved nitrogen and phosphorus compounds from it. The advantages of this technology lie in the higher assimilative capacity of plants as to phosphorus and nitrogen compared to microflora, the possibility of using biomass as a feed for fish, and the absence of repeated water contamination that is characteristic of bioreactors with microorganisms. Some undissolved phosphates contained in detritus, fish feces and periphyton biomass can be transferred to gastropod biomass available to fish. In contrast to the conventional technology of circulating water purification in which about 5.5 g phosphorous per kilogram of feed introduced into the basin is removed, this



*Source: Biomar and the Environmental Protection Agency, Denmark.	
** Source: Crab R. et al., 2007	
1-	Basins with fish
2 -	Mesh prefilter
3 -	Bioreactor with molluscs
4 -	Pump
5 -	Bioreactor with immobilized microorganisms
6 -	Phyto-reactor with duckweeds

Fig. 1 Scheme of phosphorous compounds transformation in the process of the RAS circulating water biological purification.

technology ensures the reduction in the amount of phosphorus in the waste more than twice.

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