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Ultraviolet disinfection of water in recirculating aquaculture system: a case study at sturgeon caviar fish farm

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Abstract: In this report, we present a practical example of ultraviolet (UV) water disinfection in an aquaculture facility for sturgeon caviar production. Among the methods of water disinfection in recirculating aquaculture systems, the technical approaches using ozonation or ultraviolet radiation in combination with other methods are the most effective. However, improper use of ozonation can result in excessive ozone concentrations that can cause serious harm to fish and be harmful to the environment and personnel. Therefore, we describe an example of a reagent-free ultraviolet water disinfection system. Preliminary results show that filtration followed by ultraviolet irradiation inactivates microorganisms in fish tank water. Total microbial count, total coliform bacteria, and *E. coli* (CFU/m^3) did not exceed the permissible values. The described UV system provides an irradiance of 180 W/m^2. For a pool with a water volume of 300 m^3, bacteriological purity of the water was achieved with 480 W of UV-light.

Key words: aquaculture; fish; sturgeon; recirculation system; UV water disinfection

Razkuževanje vode z ultravijolično svetlobo v recirkulacijskem akvakulturnem sistemu reje: primer ribogojnice jesetrov za prirejo iker, namenjenih za proizvodnjo kaviarja

Izvleček: V članku predstavljamo primer razkuževanja vode z ultravijolično (UV) svetlobo v recirkulacijskem akvakulturnem sistemu reje jesetrov za prirejo iker, namenjenih za kaviar. Med metodami razkuževanja vode pri gojenju rib v zaprtih akvakulturnih sistemih reje so najučinkovitejši pristopi z uporabo ozoniranja ali UV sevanja v kombinaciji z drugimi metodami. Nepravilna uporaba ozoniranja za razkuževanje vode lahko povzroči nastanek prevelikih koncentracij ozona, ki lahko negativno vplivajo na zdravje rib in škodujejo okolju in osebju v ribogojnici. Predstavljamo primer razkuževanja vode, ki temelji na uporabi UV svetlobe. Preliminarni rezultati so pokazali, da razkuževanje vode z metodo filtracije in UV sterilizacije zagotavlja učinkovito inaktivacijo mikroorganizmov v bazenu za gojenje rib, saj skupno število mikrobov, skupno število koliformnih bakterij in *E. coli* (CFU/m^3) ni preseglo priporočenih vrednosti. Opisani sistem proizvaja jakost UV sevanja 180 W/m^2, kar ob uporabi 480 W kvarčnih UV žarnic zagotavlja bakteriološko čistost vode za bazen prostornine 300 m^3.

Ključne besede: akvakultura; ribogojstvo; ribe; jeseter; recirkulacijski sistem; razkuževanje vode; UV svetloba

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1 INTRODUCTION

In recent years, in Ukraine, as in other countries, industrial farming methods in aquaculture facilities have become increasingly important. These include fish farming in recirculating aquaculture systems (RAS) (Martins et al., 2010; Bulc et al., 2011). This approach can achieve high growth rates with minimal energy costs (Zainal et al., 2021) and is economically advantageous because of the reuse of water resources and the possibility of optimizing the hydrochemical regime without depending on environmental conditions.

The development of aquaculture farms and the associated increase in production volume has led to problems with effective disinfection of water in RAS. The choice of the method and means of purification of recycled water is of crucial importance for the technological cycle of fish farming. New technologies offer alternatives to classical water treatment methods (e.g., particle filtration, biofiltration, and gas exchange) (Huyben et al., 2018). Gundula et al. (2019) consider recirculation systems as systems that incorporate a number of water purification stages, which consists of: 1) devices for removing solid particles from water, 2) biofilters for ammonia reduction, and 3) gas exchange devices for carbon dioxide removal and oxygen addition. Rearing fish in RAS may be beneficial for increased fish survival rates, when compared to standard cage systems, mostly due to stable microbial environment that prevents opportunistic microbe multiplication (Dahle et al., 2020).

UV irradiation and ozonation are the most common methods of water disinfection in aquaculture. Studies have shown that it is possible to achieve optimal conditions for the microbiological composition of water also with the combined effects of filtration, UV radiation, and ozonation (Gregersen et al., 2020; Middlemiss et al., 2015). The effectiveness of these methods, as well as their combination depends on the presence of dissolved and suspended organic compounds in the water (Semenov et al., 2021a). Overexposure to ozone can cause serious damage to fish and can be harmful to the environment (Sharrer et al., 2005). During ozone treatment, microparticles are broken down into molecular structures and then removed at different stages of filtration. This method of water purification is suitable for fish incubators that are sensitive to microparticles and bacteria in the water. However, there are arguments against the use of ozonation in RAS (Attramadal et al., 2012) as such systems require a large amount of ozone, which is mostly consumed in the reactions with organic substances, however residual ozone and reaction byproducts can be toxic for fish and live feed. On the other hand, UV irradiation of water is considered a safe alternative to ozonation. When using ultraviolet radiation, the number of microorganisms is significantly reduced (Moriarty et al., 2018) as it inactivates microorganisms through photochemical reactions of nucleic acids, which occurs in a special ultraviolet chamber (Semenov et al., 2018) with no harmful effects on fish, environment, and personnel.

According to Runia (1995), different irradiances are required for different types of microorganisms: for inactivation of bacteria and fungi from 100 mJ/cm^2 and for viruses from 250 mJ/cm^2. These relatively high doses compensate for the possible change in turbidity of the water and the change in transmittance of UV radiation energy. For example, Sharrer et al. (2005) used UV doses ranging from 75 to 1800 mW/cm^2 to achieve inactivation of coliform bacteria in rearing salmonids. However, the inactivation process is not guaranteed if suspended solids are present in the water stream. In practice, radiation intensity of at least 400 mJ/m^2 is required for the operation of fish incubators and RAS. In Ukraine, ozonation is the predominant method of water disinfection in aquaculture (Semenov et al., 2021a; Semenov et al., 2021b). In this report we present an example of an alternative solution – UV disinfection of water in aquaculture facility for caviar production.

2 MATERIALS AND METHODS

Experimental work was carried out in an aquaculture farm (Zhashkov, Cherkasy region) when growing sturgeon (*Acipenser gueldenstaedtii*) for caviar production. Fish farming was carried out in an insulated hangar. Bioload of the system was 53–55 kg of live fish per 1 m^2 of pool area. Fish were fed four times a day using commercial diet. All experimental work was carried out in a closed water supply system with a volume of 300 m^3, water temperature of 21–22 °C, pH level of 7.3–7.7, and dissolved oxygen content of 5.6–5.8 mg/l. Water purification was carried out continuously through the water recirculation channel with width of 200 mm and water flow height of 840-860 mm. The recirculation channel provides a water flow of 75 m^3/h. For UV disinfection of water, quartz lamps (type ZW80D19W) were used with the power of 80 W, lamp current of 800–1200 mA, and UV (254 nm) irradiance (d = 1 m) of 240–270 μW/cm^2. Presence of bacteria was determined with bacteriological cultures on dense nutrient media, followed by identification of phenotypic or serological properties of the studied strains.

3 RESULTS AND DISCUSSION

Among the types of UV disinfection units considered, there are two types – surface and submersible. A surface sterilizer consists of a battery of UV lamps set-up above the water. Submersible sterilizers, in which water disinfection takes place in the irradiation chamber are more efficient and reliable (Semenov et al., 2018). In order to obtain satisfactory results in terms of water quality it is necessary to continuously treat the water. For this, filtration and bacterial disinfection are used together. For the purification and disinfection of water for sturgeon fish farming in RAS we assembled a UV irradiation system schematically presented in Figure 1.

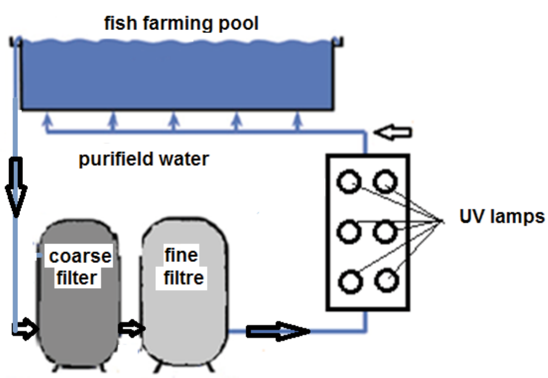

Figure 1: Scheme of the water purification and disinfection installation

The system includes the following: 1) installation for removing coarse dirt, 2) installation for removing highly dispersed impurities (fine cleaning), 3) installation for ultraviolet water disinfection, and 4) equipment for pH correction, water saturation with oxygen, water heating and electronic control system. For the inactivation of microorganisms, a 480 W UV installation has been developed, which consists of six low-pressure ultraviolet lamps with the previously described characteristics. Lamps are placed after the filtration units and fitted vertically within the water flow. They are inserted in quartz glass covers to maximize the irradiation area. The total bactericidal flow is 180 W/m^2.

The obtained results of bacteriological studies of water when growing fish are presented in Table 1.

Bacteriological studies of the water in the pool showed that ultraviolet disinfection combined with filtration provides the necessary bacteriological purity of water in pools with a volume of up to 300 m^3. With the proposed system, bacteria causing fish diseases such as *Flexibacter Cytophaga*, *Aeromonas* and mycoses (*Saprolegniales*) were not detected within first three months and after six months.

4 CONCLUSIONS

A reagent-free system for disinfecting water in fish breeding pools based on UV irradiation was assembled and tested. In the case of RAS with a water volume of 300 m^3, the proper bacteriological quality of the water was ensured for six monitored months by installing UV quartz lamps with a power of 480 W and a UV irradiation intensity of 180 W/m^2.

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Table 1: The results of bacteriological studies of water in the pool when growing fish

Indicator name	Requirements (CFU/cm^3)	Research results (days)					
		0	7	30	60	90	120
Total microbial count (CFU/cm^3 at 37 °C)	< 100	17	40	79	52	60	89
Total coliforms (CFU/100 cm^3)	-	-	-	-	-	-	-
E. coli (CFU/100 cm^3)	-	-	-	-	-	-	-

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