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Water quality in carp fish ponds: Is it safe to discharge it to watercourses?

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ABSTRACT
Any livestock production is responsible for producing a certain amount of pollution. Carp fish farming is not different. Therefore this paper aimed to monitor water quality in two carp fishponds from the region of Vojvodina (Serbia), one situated near the village Sečanj and the other at Banatska Dubica. Both are once a year discharging their effluents to nearby watercourses. The first fishpond discharges its water into the River Tamiš and the second one into the canal Danube-Tisa-Danube. Water sampling was done in autumn and summer, and subsequent analyses included the following water quality parameters: dissolved oxygen - DO, % of DO, pH, conductivity - EC, chemical oxygen demand - COD, total ammonium - TA, nitrites - NO_2^-, nitrates - NO_3^- total nitrogen - TN, orthophosphates - PO_4^{2-}, total phosphorus - TP, suspended solids - SS, chlorides – Cl^-, alkalinity - Alk., copper - Cu and zinc - Zn. Interpretation of the results was performed in line with Serbian bylaws concerning permitted water quality and ecological status/potential of water bodies, as well as with the former Fish Directive of the EU. The results revealed that most parameters were in desirable ranges i.e. I-II class, except SS, Cu, and COD are belonging to the IV-V water quality class, which is extremely unfavorable. In addition TP is exceeding limits posed by the former Fish Directive of the EU, thus posing a threat to developing the eutrophication process. Given the above, it is advisable to establish water purification for the fishpond water before discharging into watercourses. Concerning to this, priority should be given to Nature-based Solutions, such as constructed wetlands, which are characterized by efficiency, small investments, and fit well into the natural environment.

KEY WORDS: carp fishponds, water quality, EU legislation, Serbian regulation, constructed wetlands

Introduction

The Autonomous Province of Vojvodina, Serbia, is characterized by favourable ecological conditions for breeding cyprinid species in ponds. The abundance of water and plain terrain are the basic preconditions that make the area suitable for establishing carp fishponds. The hydrological network in Vojvodina is very dense, comprising many large rivers and the constructed canal network of the Hydro-system Danube-Tisa-Danube (DTD canals). All these watercourses are characterized by low velocity and relatively high temperatures in the summer months. Therefore, fish ponds that feed from such watercourses are suitable for breeding warm-water-cyprinid species of fish (Urošević et al., 2022).

In the production process of fish, water plays an essential role. Although, the cyprinid species are very resistant and can withstand large variations, in both temperature and water quality, for the reasons of better productivity and safety for consumers, the water in the ponds needs to meet certain standards. Concerning cyprinid fishpond production there are two aspects related to water. The first one is related to water quality and quantity necessary to support cyprinid fish production itself. The second one is discharging the water from fishponds after a production cycle into the environment, i.e. most often into rivers or the canal network.

In the European Union, the Fish Directive (Directive, 2006/44/EC) was the document that prescribed recommended and binding values for certain parameters of importance for fish life and their well-being. However, in Serbia, there are no restrictions concerning, neither water quality regarding fish production nor discharging water from fishponds (Urošević et al., 2021). This paper aims to present water quality monitoring in two typical carp fishponds – situated near villages Banatska Dubica and Sečanj. In addition, the results of the monitoring are compared to existing Serbian and EU legislation to discover if it is safe to discharge it to watercourses.

Material and methods

Location of selected carp fishponds

For this monitoring, two typical fishponds were chosen, both situated in the east of the Vojvodina Province (figure 1). These fishponds are located on the outskirts of the villages Banatska Dubica, 45° 15'0 6.3"N 20° 50'3 2.6" E (figure 2a) and Sečanj, 45°21'56.4"N 20°45'10.8" E (figure 2b). Both fishponds are established on low productive soil. The main cause contributing to the low productivity of the soil is the high percentage of clay, which makes the soil impermeable. Such soil is regarded as poor for crop production, but excellent for establishing carp fishponds. The source of water for the fishpond near Banatska Dubica is nearby the DTD canal, while the other one near Sečanj supplies from the River Tamiš.

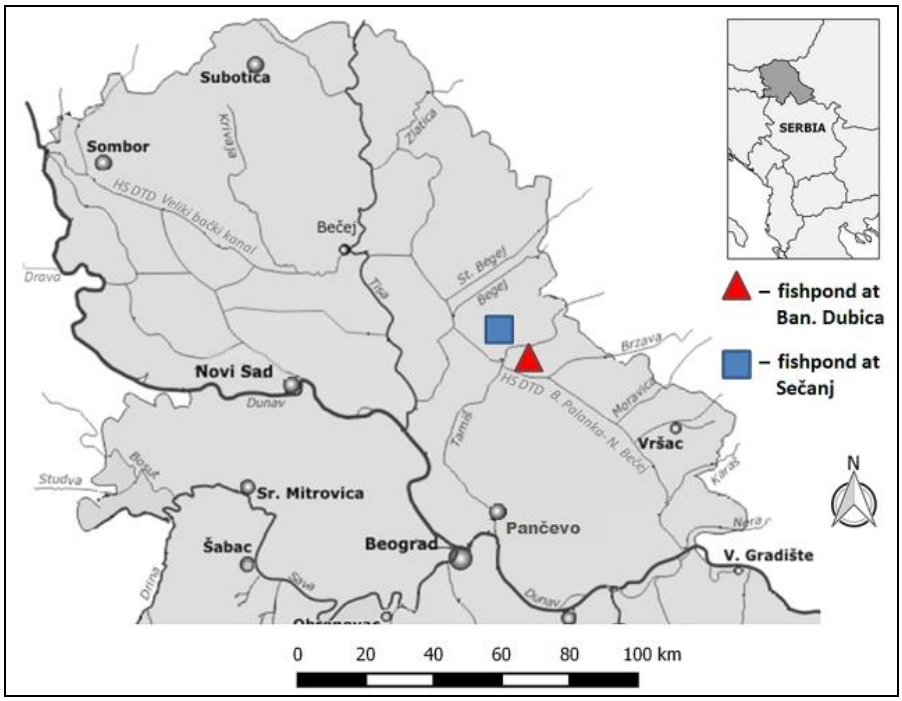

Figure 1. Locations of monitored carp fishponds at Banatska Dubica and Sečanj
Slika 1. Lokacije osmotrenih šaranskih ribnjaka pokraj Banatske Dubice i Sečnja

Figure 2. Satellite images of fishponds at Banatska Dubica (a) and Sečanj (a)
(Source: Google Earth Pro, date: 29th of March, 2019)
Slika 2. Satelitski snimci ribnjaka pokraj Banatske Dubice (a) i Sečnja (b)
(Izvor: Google Earth Pro, datum: 29.03.2019.)

Water quality sampling and analyses

Water sampling was done as a grab sample in both fishponds from a depth of 0-50 cm on two occasions on the 6th of October, 2021 and the 13th of July, 2022. Immediately after sampling water was brought to the Laboratory for Waters, Faculty of Agriculture, University of Novi Sad, where, immediately after bringing, dissolved oxygen (DO), pH, and conductivity (EC) were measured by sensory methods. Subsequently, samples were refrigerated at up to 8°C until performing further analyses. Assessing other important parameters included photometric determination of suspended solids (SS), chemical oxygen demand – COD (dichromate method), nutrient parameters – nitrogen compounds (total ammonia – TA; nitrites – NO_2^- and nitrates – NO_3^-) and phosphorous compounds (total phosphorus – TP and orthophosphates – PO_4^{2-}), chlorides – Cl^-, alkalinity – Alk. and the presence of heavy metals (zinc – Zn and copper – Cu). Sensory equipment included the oximeter, conductometer, pH-meter, and photometer for suspended solids and multiparametric photometer.

Regulation background

The Republic of Serbia is at the threshold of the European Union already for a decade. Therefore, starting from the Serbian Law on Waters from 2010, bylaws are also harmonized with the requirements of the Water Framework Directive (Directive, 2000/60/EC). The bylaws concerning limits values for discharging effluents into surface waters are:

(1) Regulation on emission limit values for pollutants in waters and the deadlines for their reaching (Regulation, 01/16) and
(2) Regulation on emission limits values for pollutants in surface and ground waters and sediments and the deadlines for their reaching (Regulation, 50/12).
(3) Also, it is worth mentioning classification intended for surface waters and assessment of the ecological status or potential of a waterbody and colouring scheme (table 1), i.e.:
(4) Rulebook on parameters of ecological and chemical status of surface waters, and parameters of the chemical and quantitative status of ground waters (Rulebook, 74/11).

According to Regulation 50/12 and Rulebook 74/11, water quality can be graded into five classes starting from I class – excellent water quality, to V class – bad water quality (table 1). Table 2. provides the designation of ecological status/potential and colouring scheme according to Rulebook 74/11.

Mentioned bylaws provide solid restrictions (in the form of limit values for certain water quality parameters) to protect the water quality of various waterbodies types. Table 1 shows the colouring scheme for the ecological status of waterbodies. In addition, table 2 presents numeric values for emission limits of pollutants, determining water quality classes (Regulation, 50/12) and ecological status/potential (Rulebook, 74/11). Hence, these limit values are not focused upon specific requirements important for fish life. The European Union's major document is the Water Framework Directive (Directive, 2000/60/EC), which requires good water quality for all water bodies within the territories of its member states. For fish well-being and fish life, the Fish Directive (Directive, 2006/44/EC) had been setting limit values of certain parameters of freshwaters needing protection or improvement to support fish life.

Table 1. Assessment of water quality status and colouring scheme according to the Rulebook (74/11)
Tabela 1. Ocena ekološkog statusa vodnih tela i bojenje prema Pravilniku (74/11)

Assessment of ecological status	**Colour**
Excellent	blue
Good	green
Moderate	yellow
Poor	orange
Bad	red

However, the Fish Directive has been repealed in 2013 by the consolidated version of the WFD (Directive, 2000/60/EC) in 2014. Currently, the WFD is used to provide "at least the same level of protection as the Fish Directive" (DEFRA & EA, 2009). Table 3 provides an overview of mandatory and guide limit values concerning water quality intended for cyprinid waters according to the directive.

Table 2. Emission limit values for water quality classes (Regulation, 50/12) and ecological status/potential (Rulebook, 74/11)
Tabela 2. Granične vrednosti emisije za klase kvaliteta vode (Uredba, 50/12) i za ekološki status/potencijal (Pravilnik, 74/11)

Param-eters	Units	Limit values for classes									
		I class		II class		III class		IV class		V class	
		50/12	74/11	50/12	74/11	50/12	74/11**	50/12	74/11**	50/12	74/11**
pH	-	6.5-8-5		6.5-8-5		6.5-8-5		6.5-8.5		<6.5;8.5>	
SS	-	25	-	25	-	-	-	-	-	-	-
DO	mgO_2/l	8.5	8.5	7	7	5	5(5)	4	4(3)	<4	<4 (2)
	% O_2	70-90		50-70		30-50		10-30		<10	
COD	mg l^{-1} O_2	10	-	15	-	30	-	125	-	>125	-
TN	mg l^{-1} N	1	-	2	-	8	-	15	-	>15	-
NO_3^-	mg l^{-1} N	1	1	3	3 (3)	6	6 (6)	15	15 (15)	>15	(>15)
NO_2^-	mg l^{-1} N	0.01	-	0.03	-	0.12	-	0.3	-	>0.3	-
TA	mg l^{-1} N	0.1	0.1	0.3	0.3 (0.2)	0.6	0.8 (0.8)	1.5	1 (1)	>1.5	>1 (1)
TP	mg l^{-1} P	0.05	0.05	0.2	0.2 (0.3)	0.4	0.4 (0.4)	1	1 (1)	>1.0	>1.0
PO_4^{2-}	mg l^{-1} P	0.02	0.02	0.1	0.1 (0.2)	0.2	0.2 (0.3)	0.5	0.5 (0.5)	>0.5	>0.5
Cl^-	mg l^{-1} Cl	50	50	100	100 (50)	150 (100)	(100)	250	-	>250	-
EC	µS cm^{-1}	<1000		1000		1500	-	3000	-	>3000	
Cu*	mg l^{-1} Cu	0.005, T=10 0.022, T=50 0.040, T=100 0.112, T=300		0.005, T=10 0.022, T=50 0.040, T=100 0.112, T=300		0.5	-	1.0	-	>1.0	-
Zn*	mg l^{-1} Zn	0.03, T=10 0.20, T=50 0.30, T=100 0.50, T=500		0.3, T=10 0.7, T=50 1, T=100 2, T=500		2.0	-	5.0	-	>5.0	-

*T- represents water hardness in mg/l $CaCO_3$; **values in brackets are referring to limit values for artificial waterbodies, while without them are for natural surface waterbodies – just for Rulebook 74/11. Note: for SS, COD, TN, NO_2^-, Cu and Zn limit values are given only according to Regulation 50/12.

Table 3. Guide and mandatory values of water quality parameters according to the Fish Directive (Directive, 2006/44/EC) for cyprinid waters
Tabela 3. Preporučene i obavezujuće vrednosti parametara kvaliteta vode prema Direktivi o ribama (Directive, 2006/44/EC) za šaranske vode

Parameters	Units	Cyprinid waters	
		Guide values (G)	Mandatory values (I)
DO	mg l^{-1} O_2	50% ≥8.0; 100%≥5.0	50%≥7.0
NO_2^-	mg l^{-1} NO_2^-	≤0.03 (0.01 mg/l N)	-
TP	mg l^{-1} PO_4^{2-}	-	0.4 (0.13 mg/l P)
TA	mg l^{-1} NH_4^+	≤0.2 (0.16 mg/l N)	≤1.0 (0.78 mg/l N)
Zn	mg l^{-1} Zn*	-	≤1.0*
Cu	mg l^{-1} Cu	≤0.04**	-
SS	mg l^{-1}	≤25	-
pH	-	-	6-9

*if water hardness is 100, but if it is 100-500 mg/l $CaCO_3$ mandatory value is 2 mg/l Zn; **if water hardness is 100, but if it is 100-300 mg/l $CaCO_3$ guide value is 0.112 mg/l Cu

Nevertheless, the Fish Directive (Directive, 2006/44) provided limit values of water quality parameters important for fish life and wellbeing. In this paper, those boundaries are used to interpret the monitored water quality in the fishponds, in absence of legislation in Serbia concerning this topic.

Results and discussion

Upon laboratory analyses, water samples from the fishponds at Banatska Dubica and Sečanj were interpreted in accordance with the Serbian bylaws (Rulebook, 74/11; Regulation, 50/12) and Fish Directive (Directive, 2006/44/EC). Results of monitoring in fishponds at Banatska Dubica and Sečanj for two dates are presented in table 4, together with an assessment of their ecological status, which is shown in a form of the differently coloured fields according to the scheme presented in table 2. The reason why the water samples are subjected to so strict classification is that, in the Serbian legislation framework, there are no limit values for effluents from fishponds that enter watercourses. In this case, water from the fishponds at Sečanj and B. Dubica is discharged into the River Tamiš and the DTD canal, respectively. Therefore, the assessment of its water quality was done in line with limit values for ecological status (Rulebook 74/11), as well as with Regulation 50/12.

Table 4. Monitored values of water quality parameters in fishponds at Banatska Dubica and Sečanj
Tabela 4. Izmerene vrednosti parametara kvaliteta vode u ribnjacima u Banatskoj Dubici i Sečnju

Parameters	**Units**	**Fishpond at Banatska Dubica***		**Fishpond at Sečanj****	
		Sampling dates			
		06.10.2021.	**13.7.2022.**	**06.10.2021.**	**13.7.2022.**
pH	-	7.65	7.44	7.23	8.59
EC	µS cm^{-1}	451	344	431	263
DO	mg l^{-1} O_2	7.25	5.75	7.11	8.22
	% O_2	84.8	60.05	84.0	85.8
SS	mgl^{-1}	76	42	20	37
Cl^-	mg l^{-1} Cl	7.9	-	10.6	-
TP	mg l^{-1} P	0.22	0.23	0.16	0.18
PO_4^{2-}	mg l^{-1} P	0.70	0.06	0.05	0.04
TA	mg l^{-1} N	0.25	0.06	0.13	<0,02
NO_2^-	mg l^{-1} N	0.01	<0.01	<0.01	<0.01
NO_3^-	mg l^{-1} N	-	<1	-	<1
TN	mg l^{-1} N	<0.5	2	<0,5	2.2
COD	mg l^{-1} O_2	27	50	18	18
Alk.	mg l^{-1} $CaCO_3$	432	-	360	-
Cu free	mg l^{-1} Cu	0.56	<0,05	0.26	<0,05
Zn	mg l^{-1} Zn	<0,02	<0,02	<0,02	<0,02

Measured values of water quality parameters are presented in table 4 and it can be seen that most parameters observed at both fish ponds fall into the I-II water quality class (coloured blue and green). Low DO was measured in the summer period in the fishpond at Banatska Dubica, TP from both dates belong to the III class. COD was also high at both fishponds (the III class) and even the IV class for summer at Banatska Dubica. Free Cu at B. Dubica in autumn was also in the IV, while in the fishpond at Sečanj was in the III class. Parameters belonging to the V class were SS (except for the measurement in autumn at Sečanj) and PO_4^{2-} in B. Dubica in autumn. The value of pH at Sečanj in summer was slightly higher than the required 8.5. In general, it can be concluded that parameters of concern in both fishponds are SS and COD, and Cu free at B. Dubica. When comparing to the Fish Directive (2006/44/EC) guide and mandatory values pH, DO, NO_2^-, Zn and TA are in accordance with either guide or mandatory values, but TP, Cu and SS are exceeding posted limits.

Natural processes occurring in fishponds due to seasonal changes may also affect water quality. The results are showing lower EC values at both fishponds in summer, indicating a lower presence of

dissolved salts compared to autumn. This is by the assumption that during summer dissolved salts, especially nutrients, are absorbed by living organisms. As their populations decline during autumn, decomposing organic matter mineralization occurs, thus contributing to the elevated value of EC. However, to confirm the influence of seasonal changes on other parameters, it is necessary to conduct systematic monitoring at least for a year.

Since some parameters are exceeding limit values and to obtain fishpond effluent of satisfactory water quality, it would be advisable to establish a wastewater treatment facility in both fishponds. It seems that the most suitable solution would represent constructed wetland solution based upon purification conducted by common reed (*Phragmites australis* (Cav.) Trin. ex Steud.). This solution is relatively low cost, fits the environment (i.e. common reed is autochthonous in the Vojvodina region) and successfully removes SS, biochemical oxygen demand - BOD (Josimov-Dundjerski et al., 2015; Li et al., 2021) and heavy metals (Saeed et al., 2021). Finally, this solution is also highly appreciated as a Nature-based Solution in Agri-Food Supply Chain (Takavakoglou et al., 2022).

Conclusions

In the regulation of the Republic of Serbia, fishpond effluents are not listed among sources of pollution and thus this potentially problematic issue remains unregulated. Water samples from two typical fishponds (sampled in two periods – autumn and summer) at Sečanj and B. Dubica were analysed and subsequently compared to the existing Serbian bylaws and with the former Fish Directive of the EU (Directive, 2006/44/EC). Due to the process of managing fishponds, water is once a year discharged into nearby watercourses. Our monitoring revealed that most of the examined parameters covered by the Fish Directive and Serbian bylaws are in line with posed limit values. However, the parameters of concern are SS, COD, and Cu. Additionally, TP exceeds limits posed by Fish Directive (2006/44/EC), thus posing a threat to the developing eutrophication process. To improve fishpond effluents it is advisable to implement treatment of a constructed wetland type – a common reed based, efficient, low-cost solution perfectly suited to the natural environment in Vojvodina Province.

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Kvalitet vode u šaranskim ribnjacima: Da li je bezbedno upuštati tu vodu u vodotoke?

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ABSTRACT
Svaka stočarska proizvodnja je odgovorna za produkciju određene količine zagađenja. U tom smislu uzgoj šarana nije drugačiji. Stoga je ovaj rad imao za cilj da prati kvalitet vode u dva šaranska ribnjaka iz regiona Vojvodine (Srbija), od kojih se jedan nalazi u blizini sela Sečanj, a drugi uz Banatsku Dubicu. Oba ribnjaka jednom godišnje ispuštaju vode iz proizvodnje u obližnje vodotoke. Prvi ribnjak ispušta vodu u reku Tamiš, a drugi u kanal Dunav-Tisa-Dunav. Uzorkovanje vode vršeno je u jesen i leto i analizirani su sledeći parametri kvaliteta vode: rastvoreni kiseonik -DO, % DO, pH, elektopropovodljivost -EC, hemijska potrošnja kiseonika -COD, ukupni amonijum -TA, nitriti -NO_2, nitrati -NO_3 ukupni azot -TN, ortofosfati -PO_4, ukupan fosfor -TP, suspendovane materije -SS, alkalitet -Alk., hloride -Cl, bakar -Cu i cink -Zn. Interpretacija rezultata je rađena u skladu sa podzakonskim aktima Srbije u vezi sa dozvoljenim koncentracijama zagađujućih materija u vodi i ekološkim statusom/potencijalom vodnih tela, kao i sa predašnjom Direktivom o ribama EU. Rezultati su pokazali da je većina parametara u dozvoljenim granicama I-II klase, osim za SS, Cu i COD koji prelaze u IV i V klasu kvaliteta vode, što predstavlja izrazito nepovoljno stanje. Dodatno, prema predašnjoj Direktivi o ribama EU, TP prevazilazi postavljene granične vrednosti što predstavlja pretnju razvoju eutrofnih procesa. S obzirom na pomenuto, preporučljivo je uvesti prečišćavanje vode iz ribnjaka pre ispuštanja u vodotoke. Pri tome, prioritet treba dati rešenjima bliskim prirodnim, kao što su mokra polja, koja se odlikuju efikasnošću, malim ulaganjima i dobro se uklapaju u prirodni ambijent.

KLJUČNE REČI: šaranski ribnjaci, kvalitet vode, legislativa EU, srpska regulativa, mokra polja