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VARIABILITY OF THE PARAMETERS CHARACTERIZING EFFLUENTS DISCHARGED FROM FISH FARMS

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Summary. This study has been undertaken in order to characterize parameters of water flowing into and out of three fish farms near Olsztyn. Quantities of pollutants discharged to water during commercial fish fattening have also been determined. The analyzed effluents were found to vary greatly in both the qualitative and quantitative properties. It was demonstrated that the use of simple wastewater treatment devices on one of the farms decreased the amount of phosphorus compounds in water discharged from the farm, but had a limited effect on the content of nitrogen compounds or BOD_5, which could have been caused by the way in which the wastewater treatment equipment was utilized. At the same time, the effluent from the same fish farm was found to contain the highest concentrations of ammonia nitrogen, probably due to the organic matter metabolism which occurred in stored sediments.

Key words: fish, fish farms, contaminants, wastewater, discharged effluents

INTRODUCTION

The current research indicates that the amount of fish captured from natural sites is decreasing year after year; in contrast, quantities of fish obtained from large commercial fish farms are on the increase. Analogously to rearing land animal, aquaculture can have an adverse impact on the natural environment. The actual effect depends mainly on the production technology applied, the feed given to fish and other environmental factors. Until now, fish farms have been perceived as ecologically clean facilities, not affecting the environment. However, in recent years, as the number of aquaculture facilities has been growing rather rapidly, quantities of contaminants reaching the environment have been increasing gradually [Maillard *et al.* 2005]. The rise in commercial fish production is not accompanied by an equally rapid growth in wastewater treatment technologies. Most aquaculture facilities do not treat their wastewater or else they do it on a very small scale.

In Poland, carp and rainbow trout are the fish species reared on a larger scale, but first attempts have been made to begin commercial production of other fish, such as sturgeon. In response to the growing market demand for such products, fish farms – while increasing production output – should consider developing technologies that would reduce amounts of pollutants reaching the environment [Rynkiewicz 2002].

In view of the above, the objective of this study has been to determine characteristics of effluents from fish farms, amounts of contaminants generated during fish fattening and the effect of a wastewater treatment installation on one of the analyzed farms on wastewater quality. The results should have some influence on how new fish tanks for salmonid fish farms are designed and the existing facilities are exploited.

MATERIAL AND METHODS

The results presented in the article have been obtained by analyzing the surface waters flowing into and out of three fish farms near Olsztyn, which carry out commercial fish fattening, mainly of rainbow trout (*Salmo gairdneri* Rich.). Analyses of the water drawn and discharged by the fish farms were conducted at monthly intervals for 18 months. The three fish farms were different in the volume of fish production, amount of drawn water and the way the wastewater was treated and discharged back to the environment.

The concrete fish raceways in which the fish were fattened drew from 2.600 to 5.040 $m^3 \cdot h^{-1}$ of water from rivers (farms A and B) or from a lake (farm C, Tab. 1). The river water was drawn directly through feeding canals, while the lake water was supplied through a polypropylene pipeline 600 mm in diameter and placed 5 meters below the water table. In fish farm A, the wastewater discharged to the environment was treated by sedimentation in separated parts of the raceways, which imitated a sedimentation basin. The other two farms did not remove pollutants from their effluents.

Table 1. Characteristics of the analyzed trout fish farms

Parameters	Unit	Farm		
		A	B	C
Source of water	–	river	river	lake
Average amount of water drawn by a farm	$m^3 \cdot h^{-1}$	5040	3600	2600
Surface area of fish tanks	m^2	3360	3720	1700
Annual fish feed consumption	$ton \cdot rok^{-1}$	126.20	165.58	86.54
Annual production of trout	$ton \cdot rok^{-1}$	90.60	113.80	64.15
Effluent treatment	–	sedimentation basins	none	none
Amount of water drawn per 1 kg of fish	$m^3 \cdot kg^{-1}$	459.9	277.12	355.04

The physicochemical analysis of the water samples comprised determinations of the reaction (pH), content of dissolved orthophosphates ($P-PO_4$), total phosphorus (P_t), ammonia nitrogen ($N-NH_4$), nitrate nitrogen ($N-NO_3$), total nitrogen (N_t), biochemical oxygen demand (BOD_5), dry residue and residue on ignition. All these determinations were achieved according to the methods described by Hermanowicz *et al*. [1999] and in the Standard Methods [1989].

RESULTS AND DISCUSSION

With respect to the fish production, the analyzed fish farms can be classified as medium ones compared to other farms in Poland and in other European countries. At the same time, they use much more water than other farms with a similar production output. On average, production of 1 kg of rainbow trout needs from 210 to 250 m^3 of water [Goldburg and Triplett 1997], but the farms we investigated needed from 277.12 to 459.90 $m^3 \cdot kg^{-1}$.

The surface waters drawn by the farms were highly different in the content of both phosphorus compounds and organic matter. The smallest amounts of these compounds were found in the waters drawn by farm A. The highest ones were detected in the water utilized by farm B. However, the total nitrogen concentration in all these waters was only slightly varied, and remained within the range of 1.61 to 1.80 mg $N_t \cdot dm^{-3}$. The other parameters of the analyzed surface water samples are presented in Table 2.

Table 2. Characteristics of the water drawn by the trout fish farms

Parameters	Farm					
	A		B		C	
	mean value	standard deviation	mean value	standard deviation	mean value	standard deviation
pH value (pH)	7.53	0.173	7.73	0.114	7.84	0.234
Phosphate (mg $P-PO_4 \cdot dm^{-3}$)	0.034	0.0187	0.145	0.072	0.152	0.107
Total phosphorus (mg $P \cdot dm^{-3}$)	0.068	0.0186	0.249	0.056	0.219	0.094
Ammonia nitrogen (mg $N-NH_4 \cdot dm^{-3}$)	0.050	0.0405	0.058	0.050	0.086	0.057
Nitrate nitrogen (mg $N-NO_3 \cdot dm^{-3}$)	0.089	0.0451	0.05	0.031	0.089	0.027
Total nitrogen (mg $N \cdot dm^{-3}$)	1.80	0.692	1.61	0.408	1.62	0.442
BOD_5 (mg $O_2 \cdot dm^{-3}$)	1.85	0.305	2.44	0.398	2.23	0.503
Total dry residue ($mg \cdot dm^{-3}$)	202.32	16.153	228.72	35.700	208.13	22.983
Organic matter ($mg \cdot dm^{-3}$)	56.37	32.46	49.52	27.42	58.81	36.75
Inorganic residue ($mg \cdot dm^{-3}$)	145.95	26.29	179.20	47.38	149.32	45.10

The content of the analyzed compounds in wasters flowing out of the farms most often depended on the amounts of the same pollutants in the drawn waters (Tab. 3). Hence. the highest total phosphorus concentrations and BOD_5 were determined in the effluent from farm B. and the lowest ones – in the effluent from farm A.

An increase in the content of pollutants in the analyzed waste water samples caused by the fish living on the farms ranged over a wide range. as seen in Table 4 (calculated as a difference between the amount of a given compound in the drawn and discharged water). Thus. the smallest average amounts of total phosphorus were discharged by farm A (0.015 mg P·dm^{-3}). and the highest ones – from farm C (0.067 mg P·dm^{-3}). An increase in the total nitrogen content was similar on all the farms. ranging from 0.08 to 0.19 mg N·dm^{-3}.

Table 3. Characteristics of the water discharged to the environment by the trout fish farms

Parameters	Farm					
	A		B		C	
	mean value	standard deviation	mean value	standard deviation	mean value	standard deviation
pH value (pH)	7.72	0.171	7.78	0.183	7.88	0.216
Phosphate (mg P-PO_4 ·dm^{-3})	0.048	0.0191	0.172	0.074	0.189	0.086
Total Phosphorus (mg P·dm^{-3})	0.083	0.0197	0.289	0.058	0.286	0.0785
Ammonia nitrogen (mg N-NH_4 ·dm^{-3})	0.085	0.0663	0.087	0.065	0.098	0.073
Nitrate nitrogen (mg N-NO_3 ·dm^{-3})	0.077	0.0201	0.073	0.052	0.091	0.027
Total nitrogen (mg N·dm^{-3})	1.88	0.606	1.80	0.421	1.78	0.599
BZT_5; BOD_5 (mg O_2 ·dm^{-3})	2.21	0.339	2.97	0.433	2.78	0.346
Total dry residue (mg·dm^{-3})	200.85	3.928	226.82	33.344	207.92	24.94
Organic matter (mg·dm^{-3})	59.75	26.46	50.35	28.597	58.87	36.65
Inorganic residue (mg·dm^{-3})	141.10	25.538	176.47	46.105	149.05	47.76

Considerable differences were detected in ammonia nitrogen. which is introduced during the fish production cycle (from 0.012 to 0.035 mg N-NH_4·dm^{-3}) and in levels of contaminants expressed by BOD_5 (from 0.36 to 0.55 mg O_2·dm^{-3}). Noteworthy was a decrease in nitrate nitrogen in the effluent from farm A.

The wastewaters discharged from the investigated farms were slightly less abundant in dry residue. which is most probably the consequence of a slower flow of water. More important, however, is the change in the characteristics of water expressed with this parameters (Tab. 4).

Namely. the content of mineral substances in these waters was lower (Tab. 4). which coincided with an increase in organic matter. The biggest decrease in mineral substances and the highest increase in organic matter were determined in the effluent from farm A. This was most likely due to the differences in the time of water flow through raceways. which was 0.8 h for farm A and 0.64 and 0.55 h for farms B and C, respectively.

Table 4. Increase or decrease in quantities of contaminants in effluents from the analyzed fish farms

Parameters	Farm		
	A	B	C
Phosphate (mg $P\text{-}PO_4 \cdot dm^{-3}$)	0.014	0.027	0.037
Total Phosphorus (mg $P \cdot dm^{-3}$)	0.015	0.040	0.067
Ammonia nitrogen (mg $N\text{-}NH_4 \cdot dm^{-3}$)	0.035	0.029	0.012
Nitrate nitrogen (mg $N\text{-}NO_3 \cdot dm^{-3}$)	**-0.012***	0.023	0.002
Total nitrogen (mg $N \cdot dm^{-3}$)	0.08	0.19	0.16
BOD_5 (mg $O_2 \cdot dm^{-3}$)	0.36	0.53	0.55
Total dry residue ($mg \cdot dm^{-3}$)	**-1.47**	**-1.90**	**-0.21**
Organic matter ($mg \cdot dm^{-3}$)	3.38	0.83	0.06
Inorganic residue ($mg \cdot dm^{-3}$)	**-4.85**	**-2.73**	0.27

*negative values bolded

The above increments in the content of pollutants in effluents seem to suggest that farm A should introduce the smallest amounts of contaminants to the environment. However. things look different when amounts of water flowing through these farms are considered and loads of contaminants are determine.

Table 5. Loads of contaminants discharged to the environment in the effluents from the three fish farms

Parameters	Farm		
	A	B	C
	Load in $kg \cdot d^{-1}$		
Phosphate ($P\text{-}PO_4$)	1.69	2.33	2.31
Total Phosphorus ($P\text{-}P_{og}$)	1.81	3.46	4.18
Ammonia nitrogen ($N\text{-}NH_4$)	4.23	2.51	0.75
Nitrate nitrogen ($N\text{-}NO_3$)	–	1.99	0.13
Total nitrogen ($N\text{-}N_{og}$)	9.68	16.42	9.98
BOD_5 (O_2)	43.55	45.79	34.32

Thus. the highest loads of phosphorus were introduced to the environment by farms B and C (Tab. 5). With respect to total nitrogen. The results are less unambiguous. i.e. farm B discharged the highest load of this element while the wastewaters from farms A an d C contained approximately the same loads of total nitrogen.

A reverse dependence was found for ammonia nitrogen. of which the highest load was discharged by farm A. where the effluent was treated by sedimentation. This was most probably caused by organic matter decomposition processes in excrements. which were removed and collected at the bottom of the sedimentation basin [Meijer *et al*. 1999]. Lower concentrations of ammonia nitrogen were determined in the wastewaters from the other two farms (B and C). which suggests that this element most probably entered the environment in the organic form together with excrements. This suggestion is confirmed by the total nitrogen load contained in the effluents from these farms.

In turn. the load of contaminants expressed by BOD_5 was the highest in the wastewater from farm B and just slightly lower in the effluent from farm A. a finding which does not correlate at all with the quantitative increase in these contaminants determined in the effluents from the three farms (cf. Tab. 4). with the highest BOD_5 values found for farms B and C. This discrepancy is the result of a much higher amount of surface water drawn by farm A compared to the other farms (Tab. 1).

The results of this study indicate that despite low concentrations of the analyzed pollutants in the effluents from the fish farms. their loads reaching the environment can be considerably high.

CONCLUSIONS

The waters discharged from trout fish farms are characterized by high variability in the content of pollutants. which is dependent on several factors. including the type of feed given to fish. the velocity of water flowing through raceways and the amount of water drawn by fish farms. The technology for removal of excrements in separated sedimentation zones. described in the article. is quite efficient in removing phosphorus compounds. However. due to the decomposition processes which take place in sediments. the content of nitrogen compounds and contaminants expressed with BOD_5 in wastewater is highly variable.

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ZMIENNOŚĆ PARAMETRÓW CHARAKTERYZUJĄCYCH WODY POPRODUKCYJNE Z GOSPODARSTW RYBACKICH

Streszczenie. W pracy przedstawiono charakterystykę wody dopływającej i odpływającej z trzech gospodarstw rybackich zlokalizowanych w okolicy Olsztyna. Określono również ilości zanieczyszczeń wprowadzanych do wody podczas przemysłowego tuczu ryb. Stwierdzono dużą zmienność parametrów charakteryzujących wody poprodukcyjne zarówno pod względem jakościowym, jak i ilościowym. Wykazano. że zastosowanie prostych urządzeń oczyszczających w jednym z gospodarstw wpływa na spadek zawartości związków fosforu w odprowadzanych wodach. natomiast ma ograniczony wpływ na zawartość związków azotu i BZT_5, co związane jest z prowadzonym sposobem eksploatacji urządzeń. Jednocześnie w gospodarstwie tym w odpływającej wodzie stwierdzono najwyższe stężenia formy amonowej azotu spowodowane prawdopodobnie zachodzącymi przemianami materii organicznej w magazynowanych osadach.

Słowa kluczowe: ryby, gospodarstwa rybackie, zanieczyszczenia, ścieki, wody poprodukcyjne