Investigations on the wastewater of a flow-through fish farming system

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Abstract: European and Hungarian fish consumption has been increasing for years. Intensive fish production is one potential methods to meet the ever-increasing demand of Hungarian consumers. However, for the sustainable growth of production, it is necessary to tackle one of the important problems of this type of fish production: reducing the nutrient content of the effluent water. Wetland can be a perfect application to solve the problem. In this research, we examine the efficiency of wastewater treatment in a fish farm where the effluent feeds the Szarvas-Békésszentandrás oxbow system. The current theoretical nutrient retention capacity of the wetland—based on literary data—is 53–61% for nitrogen (N), 76–84% for phosphorus (P) and 80–91% for chemical oxygen demand (COD). In recent years, the production capacity of the plant has increased to 500 T/year and a new pre-settling and drum filter were added to the filtration, and thus the deterrent effect of the filtration system in 2014–2017 was 74% for "N", 63% for phosphorus and 83% for COD. The efficiency of the wetland was demonstrated by measurements carried out by an accredited independent laboratory proving that no limit value has been exceeded for the last 15 times. We can conclude that the wetland is able to carry out its tasks in the long term, independently of the season, and to ensure that effluent water does not pose a significant impact to the natural environment.

Keywords: intensive fish culture, wetland, wastewater

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Introduction

Some changes have been observed in the World's fish production for decades. The growing demand for fish consumption is increasingly less met by stagnant catches of natural water fishing, so this will only be fulfilled by growing aquaculture. Today, almost half of the fish consumed come from fish farms. Under Hungarian domestic conditions, this claim is even more true. Pond fish production and precision fish farms in Hungary are responsible for almost 80% of the fish on the plate. Noteworthy, fish consumption in the country is still low, although growing steadily. In order to meet the growing demand for a fish from a healthy, controlled environment, it is necessary to expand the production (Mahal 2018). The development can either be made by increasing the area of the current extensive farms (meaning considerable cost and labour input) or the production could be intensified. The latter can be a solution to growing production, but—as opposed to extensive farming—it leaves a significant ecological risk. The three main areas with the highest risks are a significant part of the feed used being from an unsustainable source, high energy consumption and, finally, the wastewater of the intensive system placing a strain on the environment. In this research, we are dealing with this latter problem.

Although the outlet water of an intensive fish farm typically does not contain toxic substances, a significant load of ammonium, nitrate, phosphorus, high organic matter and suspended solids, resulting from fish metabolism products and unconsumed nutrients, can pose a biological risk (van Rijn 1996). In a basic environment, ammonium ion can become poisonous for many organisms, while nitrate can directly be uptaken by plants and thus accelerates eutrophication if available in high quantities. Plants can only uptake phosphorus in a reactive form, therefore a significant proportion of this element is deposited in sludge (Ördög, 2000). The high content of organic and suspended materials contributes to the formation of deep soft mud and the development of anaerobic conditions (Primavera 2006). The latter is not only directly dangerous by killing living creatures in the pond bottom but also activates the phosphorus deposited in the sludge, which becomes available to plants and bacteria, thus accelerating the eutrophication process (Ördög 2000). The described processes are particularly beneficial for cyanobacteria, which, in a large mass, cause algae bloom. It makes not only off-flavour in fish and water, but also turn pH and oxygen to extreme values, which finally leads to the disappearance of sensitive species, opening the spreading of invasive species (Oberemm et al. 1999, Havens, 2008). Inadequately treated outlet water also has a detrimental effect on local wildlife and makes the proper management of the wetland fed by the fish farm wastewater impossible. Thus, wastewater treatment is a crucial point of modern, sustainable fish farming. Numerous solutions exist to solve the problem, but multi-species wetlands can provide an economical option. These semi-natural communities help to transform the organic and inorganic substances of the outlet water into a form of organic materials (Zhang et al. 2011), easily transformable to woody biomass (e.g., willow coppice), to herbaceous biomass (e.g., reed, sedge or tangle), to floating algae or, through the food chain, even to marketable fish meat (Vymazal, 2010).

The framework for long-term, sustainable use of natural resources is set by official regulations, which of course also bind fish farmers. The water licence for fish management facilities shall include the parameters and their threshold limits of the outlet water, which must be regularly sampled and examined by an accredited laboratory (27/2005. (XII. 6.) KvVM regulation). The results of these official analyses objectively illustrate the impact of the fish farm on its environment.

Materials and Methods

The sample area is located in Szarvas. The targeted fish farm is a flow-through, African catfish producing plant that is one of the largest intensive fish farms in Hungary. Outlet water is driven to Szarvas-Kákafok Holt-Körös through a multi-pond wetland system that includes three stabilising ponds, a fish pond and a pond with water plants which filter out the most important nutrients. Wetland was developed in the framework of the SUSTAINAQUA project. The researchers carried out preliminary studies using several plants and fish species, and subsequently proposed the development of a five-pond water purification wetland. According to preliminary calculations, this system is able to remove the following substances on a daily basis (*Table 1*).

Table 1. Absorption of the wetland owned by Szarvas-Kft kg/day (based on Gál et. al 2009) (VSS=Volatile Suspended Solid)

Water temperature range	N removal	P removal	VSS
10–15 °C	35.5	4.3	233.7
15–20 °C	68.5	4.4	224.1
20–25 °C	88.9	9	451.9

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Previous tests revealed that the wetland fulfilled its role; a significant amount of organic and inorganic materials from the outlet water of the fish farm was removed (Gál et al., 2009, Gál et al., 2003, Kerepeczki et al., 2003), and meanwhile, it produced economic value through biomass production. In the experimental system, 89.4–94.4% of the Total-N, 69.6–91.2% of Total-P, and 68.7–89% of COD was removed by the biologi-

Table 2 Some parameters of the outlet water (threshold limit: maximum value determined by the

Date	pH	COD (mg/l)	BOD (mg/l)	NH_4-N (mg/l)	Total inorganic-N (mg/l)	Total N (mg/l)	Total-P (mg/l)	TSS (mg/l)
24/02/2014	7.5	*75.8*	8.1	*15.8*	15.8	*16.9*	2.6	8.0
30/03/2014	8.1	45.0	5.6	*8.1*	8.7	8.9	1.5	2.0
13/05/2014	7.9	36.0	4.6	4.4	4.6	10.8	1.5	16.3
05/08/2014	7.9	46.0	9.3	4.9	5.0	9.8	1.8	16.0
04/11/2014	7.9	38.0	5.6	4.5	4.7	5.2	1.5	4.0
24/02/2015	8.1	72.0	16.2	4.5	4.5	20.0	1.9	20.0
12/05/2015	7.9	69.0	22.0	4.9	4.9	18.7	1.9	44.4
11/08/2015	8.1	63.0	15.1	4.5	4.6	23.3	2.0	26.5
17/11/2015	8.0	48.0	4.0	4.6	4.6	23.9	2.0	10.7
23/02/2016	8.0	58.0	11.5	4.3	4.3	11.5	1.9	2.6
10/05/2016	8.2	66.0	11.5	4.3	4.6	9.1	1.6	16.0
30/08/2016	8.0	52.0	11.5	4.0	4.1	8.5	2.0	8.3
22/11/2016	7.9	55.0	16.5	4.4	4.5	14.5	1.9	24.7
03/04/2017	7.8	66.0	14.2	4.8	4.9	8.9	1.2	13.0
09/05/2017	7.9	62.0	8.6	4.9	4.9	9.9	1.9	7.4
22/08/2017	7.8	48.0	4.5	4.6	4.6	8.9	1.8	17.0
21/11/2017	7.9	46.0	17.9	4.9	4.9	8.3	1.5	6.2
Average	7.9	55.6	11.0	5.4	5.5	12.8	1.8	14.3
SD	0.2	12.0	5.4	2.8	2.8	5.7	0.3	10.6
Minimum	7.5	36.0	4.0	4.0	4.1	5.2	1.2	2.0
Maximum	8.2	75.8	22.0	15.8	15.8	23.9	2.6	44.4
Threshold limit	6.5-9	75.0	25.0	5.0	25.0	30.0	2.0	50.0

cal filtration system. In the case of the final operating-size wetland, retention of N 53%–61%, P 76–84%, COD 80–91% was expected. Further results of the experiment included that the return of the investment costs of the wetland could be recovered in 2017.

In this research, the effectiveness of the wetland system built 11 years ago was examined by analysing the data from regular independent, accredited measurements in the framework of the self-monitoring plan. The measurement was made at the release point (where the wastewater enters the receiving water body). During four years (2014–2017), four measurements per year were made: in February, May, August and November. The analysed parameters were:

- pH
- chemical oxygen demand - COD (mg/l)
- biological oxygen demand - BOD (mg/l)
- ammonium nitrogen - NH4+-N (mg/l)
- Total inorganic N (mg/l)
- Total N (mg/l)
- P (mg/l)
- suspended solids (mg/l)

Results

Measured parameters are described in *Table 2*. The results of the 17 measurements are not uniform. In the case of the first two measurements (February and March 2014), the filter unit was unable to lower the emissions below the required threshold. The exceedance of the limit value was barely 1% for COD values for the February measurement, but was 32% for P and 216% for NH4+-N. The reason for this was that, due to the increased production, a 100 µm drum filter unit was installed in the system in the second half of 2013. Although the effect of this intervention began to take affect at the beginning of 2014, the system fine-tuning was only completed in spring 2014. For the next measurement, only NH4+-N was exceeded (62%). In the next period, the wetland and drum filtration always completed the desired emission values.

Discussion

The measured values clearly showed that the previous scientific work (Gál et al. 2009, Gál et al. 2003, Kerepeczki et al, 2003) assessed the ability to process wastewater under the given circumstances well. Moreover, after a minor technological change, the desired emission values can be ensured even with a more than 60% increase in fish production. On the basis of preliminary measurements, with a feed coefficient of 1.1 (i.e., 1.1 kg feed is necessary for the withdrawal of 1 kg of fish meat) and 500 tonnes of fish production per year, the annual COD content of the wastewater is 398 t, while it contains 37.3 t NH4+-N, 59.3 t total nitrogen, 5.8 t of total phosphorous and 228 t of TSS. The wetland filters a significant proportion of these substances (COD 83%, NH4-N 82%, total-N 74%, total-P 62%, TSS 92.4 t). Its filtering efficiency is the same as the calculations previously made by the authors. All these results, based on the measurements, are provided with no significant deviation on the effectiveness of filtration in different stages of the year.

Based on the above results, it can be concluded that a well-designed filter unit is able to provide sufficient filtration efficiency, with appropriate control and minor modifications. This means that in the case of sustainable feed and energy sources being available, domestic fish production can be intensified without significant damage to the environment. A further improvement could be the possibility that at least part of the wetlands would be designed to produce economic value in order to increase the profitability of fish farms.

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