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Research Article

RISK ASSESSMENT OF SURFACE WATERS ASSOCIATED WITH WATER CIRCULATION TECHNOLOGIES ON TROUT FARMS

Marcin Sidoruk[1], Józef Koc[1], Ireneusz Cymes[1], Małgorzata Rafałowska[1] Andrzej Rochwerger[1], Katarzyna Sobczyńska-Wójcik[1], Krystyna A. Skibniewska[2] Ewa Siemianowska[2], Janusz Guziur[3], Józef Szarek[4]

[1] Department of Land Reclamation and Environmental Management, Faculty of Environmental Management and Agriculture, University of Warmia and Mazury in Olsztyn, Plac Łódzki 2, 10-756 Olsztyn, Poland, e-mail: marcin.sidoruk@uwm.edu.pl

[2] Department of Security Rudiments, Faculty of Technical Sciences, University of Warmia and Mazury in Olsztyn, Heweliusza 10, 10-719 Olsztyn, Poland

[3] Department of Fish Biology and Breeding. Faculty of Environmental Sciences, University of Warmia and Mazury in Olsztyn, Oczapowskiego 14, 10-719 Olsztyn, Poland

[4] Department of Pathophysiology, Forensic Veterinary Medicine and Administration, Faculty of Veterinary Medicine, University of Warmia and Mazury in Olsztyn, Oczapowskiego 13, 10-719 Olsztyn, Poland

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ABSTRACT

Dynamic development of aquaculture has led to an increasing impact on the status of surface waters. Fish production generates wastes that, at high concentrations, may present a serious risk to the aquatic environment. Studies on the assessment of the impact of water management technologies in trout production on the quality of surface waters were conducted in 2011. Six farms were selected for the studies and were divided into two groups based on water management solutions (n = 3): farms with a flow through system (FTS) and farms with a recirculation aquaculture system (RAS). On all farms, water measurement points were set and they depicted the quality of inflow water, the quality of water in ponds and the quality of outflow water. The studies did not demonstrate any impact of applied technology on electrolyte conductivity or calcium and magnesium concentrations in outflow water from a trout operation. In addition, it was found that the use of water for production purposes resulted in a slight increase in phosphorus and total nitrogen concentrations in waste waters.

Keywords: trout production, physical and chemical water properties, water contaminations.

INTRODUCTION

Cold, high quality inflow water which is usually taken from neighbouring rivers and streams or efficient sources is essential for maintaining a high level of trout production. The dynamic development of aquaculture has caused an increasing impact on the quality of surface waters. Fish production generates wastes (uneaten feed, excrements, chemical compounds and medicinal products supplied to ponds) that at high concentrations may present a serious risk to the aquatic environment [Koc, Sidoruk, 2013, Mehmet, Hüseyin, 2014]. Water contamination in fish production ponds influences the growth of microorganisms, including those harmful to fish and organisms inhabiting reservoirs where the water from fish ponds is transferred.

Pond management requires that breeding or rearing technologies combine the potential and economic production efficiency and determine the impact of these activities on the environment. Therefore, it is important to identify hazards and conflict situations found in the environment and caused by fish production in ponds [Prądzyńska, 2004; Sidoruk, 2012].

The objective of the studies was to determine the impact of water management in trout production on the quality of surface waters.

MATERIALS AND METHODS

The studies that consisted in assessing the impact of water management technology in trout production on the quality of surface waters were conducted in 2011. Six farms were selected and divided into two groups based on an applied water management solution, n = 3. One group consisted of farms with a flow through system (FTS) while the other group included farms with a recirculation aquaculture system (RAS).

On all farms, water measurement points were established and depicted the inflow water quality, the pond water quality and the outflow water quality. On the selected points, the analyses of water (in situ) were performed in spring (in April and May) and in autumn (in October and November) at monthly intervals. With a YSI 6600 multi-parametric probe designed for testing physical water parameters, oxygen saturation (%) and electrolytic conductivity (μS/cm) were determined. Water samples were taken for laboratory analyses from the same locations. The averaged water samples were collected into 5 dm^3 containers made of polyethylene, fixed and transported to a laboratory. The following measurements were taken: BOD_5 – with the respirometric method on an OXI-Top apparatus; nitrate nitrogen (V) – $N\text{-}NO_3$ colometrically with disulfanilic acid; nitrate nitrogen (III) – $N\text{-}NO_2$ colometrically with sulfanilic acid; ammonium nitrogen $N\text{-}NH_4$ – colometrically with a Nessler's reagent; Kiejdahl's nitrogen, N_{kj} – with distillation after mineralization in a sulphuric acid; total phosphorus (P_{og}) – colometrically after mineralization with ammonium molibdenate and tin dichloride as a redactor; and Mg^{2+} with the colorimetric method with titanium yellow and Ca^{2+} with atomic mass spectrophotometry.

RESULTS AND DISCUSSION

The concentration of oxygen originating from phytoplankton photosynthesis in a pond ecosystem depends on a variety of factors, such as temperature, water transparency, solar radiation and content of nutrients. It may constitute up to 80% of the oxygen input in a pond ecosystem [Jawecki, Krzemińska 2008]. Deviations in the content of oxygen are proportional to the fertility of a fish pond. The concentration of oxygen in the water is influenced by such factors as water temperature and transparency, content of nutrients and sunlight. It is also significantly impacted by the individual characteristics of ponds and procedures to which they are subjected [Jawecki 2008].

Inflow waters that supplied rearing ponds were very well-oxygenated with the concentration of dissolved oxygen ranging from 60.4% to 127.7%, of which 50% of the results were within the 74.1–101.1% range (Figure 1). On the FTS fish farms, there was an increase in the oxygenation level of outflow water by approx. 10.3% whereas on the RAS farms, the concentration of oxygen in water was reduced by approx. 29%. In the ponds with water recirculation, despite intensive trout production, there was a minor reduction of the oxygen content in outflow water, which was generated with artificial water aeration (the use of mechanical aerators or pure oxygen) to create optimal conditions for fish.

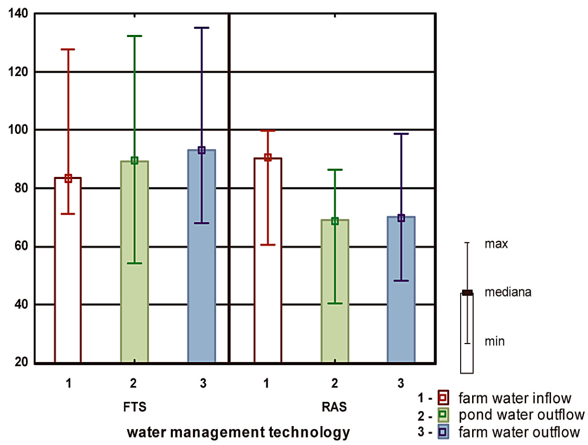

Figure 1. Oxygen saturation of inflow and outflow waters on trout production facilities (%)

Electrolytic conductivity of water corresponds to its content of mineral contaminations, a higher level of contamination was correlated with higher conductivity. Based on the value of electrolytic conductivity, it is possible to determine the degree of water salinity and the content of solutes and dry residues [Macioszczyk, Dobrzyński 2002].

Based on an analysis of electrolytic conductivity in inflow waters it was found that the median of its values was comparable on all farms and ranged between 352.5 μS/cm on the RAS farms and 372.0 μS/cm on the FTS farms (Figure 2). The maximum values of electrolytic conductivity in inflow waters on the FTS facilities did not exceed 431.0 µS/cm, whereas for the RAS farms this parameter did not exceed 402 µS/cm and, in both cases, these values were typical of flowing surface waters.

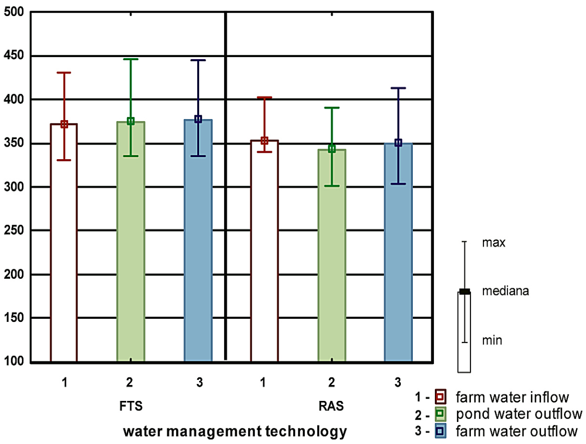

Figure 2. Electrolytic conductivity in inflow and outflow waters on trout production facilities (µS/cm)

The analysis of the results did not demonstrate any impact of applied technology on the values of electrolytic conductivity in outflow waters on trout production facilities. By assessing the changes in electrolytic in waste water outflowing from the FTS and RAS farms, it can be concluded that in the first group there was an increase in electrolytic conductivity by 5 µS/cm, while in the other group it was reduced by 2.5 µS/cm.

The water used to supply the trout production operations had a relatively low BOD_5 value and its median in the experimental period ranged from 2.07 mg/dm^3 (FTS) to 2.18 mg/dm^3 (RAS), of which 50% of the results with flow-through systems were in the 1.40–2.46 mg/dm^3 range and in the case of RAS farms – in 1.46–4.24 mg/dm^3 (Figure 3). Periodically, BOD_5 slightly exceeded the reference values for inland waters that are the habitat for salmonids (the Regulation by the Minister of Environment of October 4, 2002, Dz. U. Nr 176). Such a situation could have been caused by an increased inflow of contaminations, e.g. as a result of wash-out from fields or uncontrolled contamination of waters located above the farms.

The analysis of the results demonstrated the impact of applied water management technology on the increase of BOD_5 in outflow waters from tour production operations. By analyzing the changes in BOD_5 in the individual types of water management it was found that in post-production water outflowing from the FTS farms

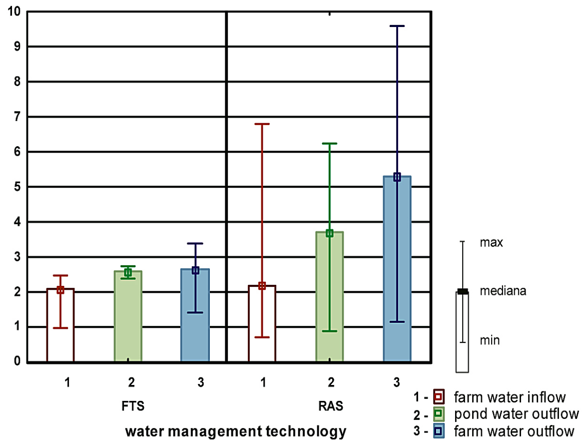

Figure 3. BOD_5 values in inflow and outflow water on trout production facilities (mg/dm^3)

there was an increase in BOD_5 by approx. 0.56 mg/dm^3, whereas on the RAS farms this increase was more significant amounting to, on average, 3.11 mg/dm^3.

In pond water, phosphorus is found as phosphate ions, being a product of orthophosphoric acid dissociation and as dissolved organic phosphorus. In aquatic ecosystems, its main function is to regulate biological production as the basic biogene for the synthesis of organic compounds, thereby influencing the fertility of waters [Raczyńska, Machula, 2006, Sindilariu et al. 2009].

In inflow waters that supplied the farms, phosphorus was mainly found in an organic form and constituted on average 57% P_{og} at inflow on the FTS farms and 52% at inflow on the RAS farms. The median of total phosphorus concentration in inflow waters that supplied the trout production operations was comparable for both groups of farms: 0.07 mg/dm^3 ranging from 0.01–0.18 mg/dm^3 on the FTS farms and at 0.09 mg/dm^3 (0.04 – 0.16 mg/dm^3) on the RAS farms (Figure 4). After using water for rearing purposes, there was a slight increase in the concentration of P_{og} in the outflow of the examined operations. By analyzing the increments of phosphorus concentration of both farms groups, it was found that the increase of P_{og} in waste waters was smaller on the FTS farms (on average by 0.03 mg/dm^3) than on the RAS farms (0.06 mg/dm^3).

The slight increase in the concentration of phosphorus compounds in outflow waters could have been caused by that fact that fishery production is targeted at intensive weight gains, which results in intensive fish feeding. It is estimated that only a minor part of the compounds found in feed is incorporated into fish biomass, with the majority

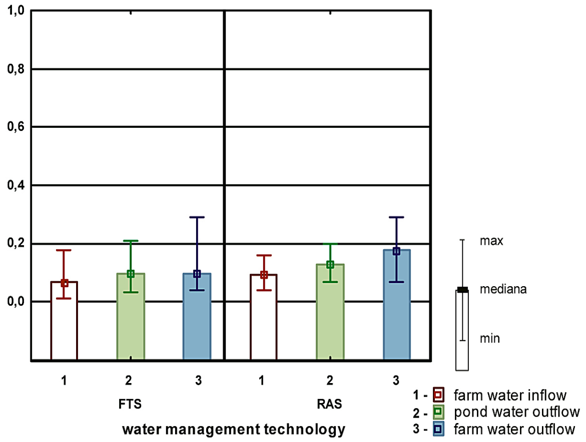

Figure 4. Content of P_{og} in inflow and outflow waters on trout production facilities (mg/dm^3)

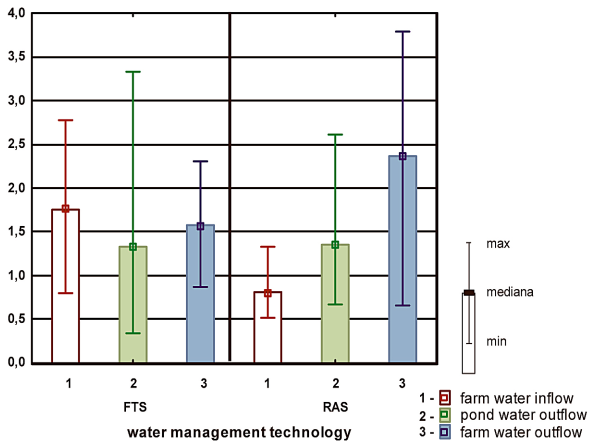

Figure 5. Content of $N_{og.}$ in inflow and outflow waters on trout production facilities (mg/dm^3)

being left in water or excreted by fish (Pulatsu et al. 2004; Tucholski, Sidoruk, 2013). It is estimated that of the feed put into fish ponds, only 5–20% of the matter is incorporated in the fish body and the rest is left in water contributing to its contamination [Goryczko 1999; Sidoruk et al., 2013].

Nitrogen accesses water mainly as mineral compounds originating from of organic nitrogen compound decomposition processes, precipitation and soils. In water, it is found in forms with a different degree of oxidation, in organic and inorganic complexes and as free dissolved nitrogen. Microbiological conversions of nitrogen in the aquatic environment are analogous as in soil. In water, organic nitrogen is most commonly found as protein, amino acids and non-protein organic compounds, i.e. urea, amines, pyridines and purine. In natural waters, it is produced from dead animal organisms and plants as well as feed residues [Koc, Sidoruk, 2013].

In inflow waters that supplied the FTS farms, nitrogen was mainly found in a mineral form that constituted 57% N_{og} whereas on the RAS farms there was an advantage of the organic form that amounted to 52% of total nitrogen. The median of total nitrogen concentration at inflow on the FTS farms was 1.76 mg/dm^3, ranging from 0.80–2.78 mg/dm^3. On the RAS farms, the median of N_{og} in inflow waters was lower, amounting to 0.80 mg/dm^3 in the range of 0.51–1.33 mg/dm^3 (Figure 5).

After using waters in trout production, it was found that there was a reduction of N_{og} concentration by 0.19 mg/dm^3 in waste waters on the FTS farms. The situation was opposite on the RAS farms where there was an increase of N_{og} by approx. 1.56 mg/dm^3, which did not generate any unfavourable conditions for organisms in the waste water reservoirs.

Magnesium compounds in water mainly originate from the process of dissolving minerals such as dolomites or lodestones. A change in the concentration of magnesium in surface waters is associated, among others, with humic compounds found in water. These substances may be present in a dissolved or colloidal form forming magnesium-humic complexes. The ability of humic substances to bind magnesium cations largely depends on reaction (pH) and, consequently, also on the degree of dissociation of functional groups [Wezel et al. 2013]. In general, a much higher concentration of calcium is detected in comparison to magnesium, most probably due to intensive uptake of this element by plants and its concentration in precipitation [Skorbiłowicz 2013].

The content of magnesium in inflow waters for both groups of farms was low and on the FTS farms the median was 7.5 mg/dm^3, ranging from 0.5–13.1 mg/dm^3 whereas in inflow waters on the RAS farms it was slightly higher and amounted on average to 8.6 mg/dm^3 ranging within 5.3–15.0 mg/dm^3 (Figure 6).

A slightly higher concentration of magnesium in inflow waters on the RAS farms could have been impacted by different geological and soil conditions over the areas of drainage basins of watercourses that supplied the operations. Based on the analysis of the results, no impact of applied technology on the concentration of magnesium in outflow waters was found. By assessing the changes of Mg^{2+} concentration in outflow water on the FTS farms, it became evident that there was a slight increase in magnesium concentration by approx. 2.6% (0.2 mg/dm^3) whereas on the

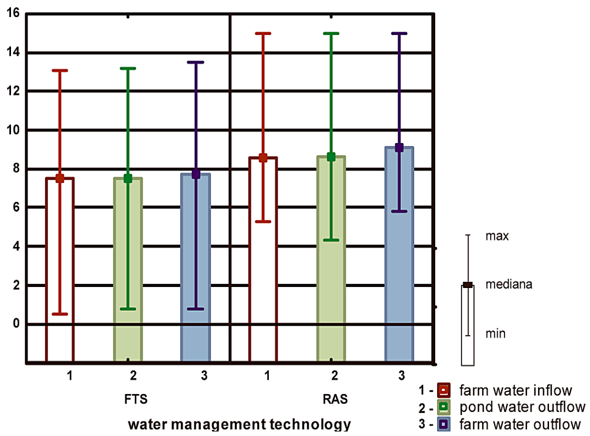

Figure 6. Content of Mg^{2+} in inflow and outflow waters on trout production facilities (mg/dm³)

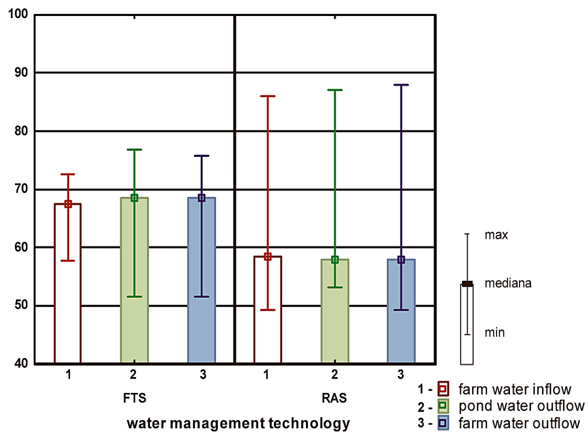

Figure 7. Content of Ca^{2+} in inflow and outflow waters on trout production facilities (mg/dm³)

RAS farms the increase in magnesium concentration was slightly higher, amounting to approx. 0.55 mg/dm³ (6.0%).

In surface waters, calcium is found as dissolved calcium carbonate and its content is determined by the presence of carbon dioxide in water [Sidoruk Skwierawski 2006; Degefu et al. 2011]. Calcium is an element which, together with magnesium, carbonates and sulphates, determines the hydrochemical type of most circulating waters in the drainage basins of the early post-glacial zone and its high content in surface waters mainly results from its intensive wash-out from soils [Sidoruk Skwierawski 2006]. In a moderate climate, it is intensively washed out of soil and this process is prompted by the acidification of precipitation. An appropriately high concentration of calcium in water is important due to its buffering capacity and for primary production, ensuring a sufficient concentration of CO_2 for photosynthesis [Degefu et al. 2011].

The results of the determination of calcium content in inflow waters demonstrated that its concentration was low and comparable for all operations: on the FTS farms it was 67.4 mg/dm³ ranging from 57.8 to 72.6 mg/dm³ whereas on the RAS farms it amounted to 58.4 mg/dm³ (49.2–86.0 mg/dm³). Throughout the entire experimental period, waters used to supply the ponds did not exceed the reference values for quality class No 1 (the Regulation by the Minister of Environment of November 9, 2011; Dziennik Ustaw Nr 257).

In waters used for breeding purposes, no impact of the activities on the content of calcium in water was observed. At the outflow from the FTS farms, there was a slight increase of Ca^{2+} concentration by 1.1 mg/dm³ whereas on the RAS farms a reduction of 0.5 mg/dm³ was recorded.

CONCLUSIONS

1. The applied water management technology did not impact electrolytic conductivity in inflow waters on the trout production operations. On the farms with a flow-through system (FTS), there was a slight increase of electrolytic conductivity (by approx. 5 µS/cm in waste water), whereas on the farms with recirculation aquaculture systems (RAS) it was reduced by 2.5 µS/cm.
2. In outflow waters on the FTS farms, there was a slight increase in BOD_5 in relation to inflow waters (0.56 mg/dm³), while on the 4 RAS farms the increase of BOD_5 was more pronounced – amounting to 3.11 mg/dm³.
3. As a result of using water for rearing purposes, there was a minor increase in the concentration of phosphorus in outflow waters on both types of farms. In waste waters outflowing from the FTS farms, the increase of P_{og} was 0.03 mg/dm³, whereas on the RAS farms it was slightly higher at 0.06 mg/dm³.
4. The impact of the type of water management technology on the concentration of total nitrogen in post-rearing waters was recorded. On the FTS farms, there was a reduction of nitrogen in waste waters in relation to inflow waters by 0.19 mg/dm³, while on the RAS farms, there was an increase in the concentration of N_{og} by approx. 1.56 mg/dm³, which did not create unfavourable conditions for organisms inhabiting receiving water reservoirs.

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