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Short communication

A description of ammonium content of output waters from trout farms in relation to stocking density and flow rates

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Abstract

Daily levels of ammonium content in the outflow water of an intensive trout farm and of a mountain pond stocked with rainbow trout were monitored. Output water was sampled for 30 days and analysed every 30 min by an automatic ion selective electrode system (Applikon ADI 2013); input water was also monitored. The ammonium output level was influenced more by atmospheric events than nitrogen excretion by fish. Observed data confirmed an overall ammonium excretion model previously estimated in both laboratory and field conditions. The high water flow, that characterises the intensive trout farm where the observations were made induced a high dilution of metabolites. Consequently, if the peaks of ammonium output did not reach values of 0.35–0.40 mg l^{-1} the environmental impact was limited and not easily detected. Our results allow us to affirm that the optimal level of water flow rate for effective zeolite-operated filtration is around 10.3 l t^{-1} s^{-1}.

Keywords: Fish; Ammonium; Excretion; Waste; Fish culture; Pollution

1. Introduction

Intensive fish farming induces modification of river and costal ecosystems; consequently, the control of waste waters is essential to manage fish farms properly. One of the most important pollutants is nitrogen from both endogenous and exogenous production of considerable quantities of catabolites. Thus, in order to include fish production within a sustainable agriecosystem (Mumpton and Fishman, 1977; Bergero et al., 1996, 1997), it is essential to set an acceptable level of ammonium content in the effluent of trout farms, as well as to determine suitable methodologies for curbing it.

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In a previous study (Bergero et al., 1994), ammonium production was calculated for young trout either fasted (4.3 μg per gram of fish h^{-1}) or restrictively fed (1.2% of the live weight, 12.4 μg per gram of fish h^{-1}); afterwards, the ammonium output was measured in a pilot fish culture plant with 200 kg of fish (Bergero et al., 1996); that allowed the formulation of a model of NH_4^+ output from intensive fish farming, that has been checked in the present work.

The possibility of filtering the effluents using zeolite (Bergero et al., 1996) was taken into account: indeed zeolites are natural materials which are effective in the captation of ammonium ions from animal wastes, particularly from aquaculture (Mumpton and Fishman, 1977; Miner, 1983; Watten and English, 1985; Dryden and Weathersley, 1989; Passaglia and Azzolini, 1994; Pond, 1995). However, these filters filled with a granular (3–8 mm diameter) Cuban clinoptilolite containing (70%) zeolitites and a Neapolitan yellow phillipsite tuff (42% of phillipsite and 10% of chabazite; Bergero et al. (1996)) were ineffective if the ammonium content in water was below 0.35–0.40 mg l^{-1}. By means of filtration on a large scale by natural phillipsite zeolites it is possible to decrease the ammonium content of the waste waters by up to 67%, but the reduction can be achieved only if the ammonium concentration at the input of filter is such as to allow the zeolite to capture the ammonium. If the ammonium level is below the threshold, the zeolite will preferentially capture other cations such as potassium and, in a subordinate degree, sodium, calcium and magnesium.

The objective of this research is to measure the trend of ammonium content levels in trout farms over a long term, identify those environmental and managerial factors which could change output levels and determine if the use of zeolite filters can be recommended under field conditions to curb ammonium pollution from in-stream fish farms.

Present European legislative recommendations adopted by the Countries of the EU emphasise the optimisation of the ratio of biomass and the output of nitrogen catabolites to water flow (actions EU 91/271/CEE and 91/676/CEE in Gazzetta Ufficialle della Reppubblica Italiana, 1996). Therefore, two trout farms with very different characteristics of production capacity and operating conditions were chosen to be monitored for analysis to obtain information towards making provisions for the pollutive effects of intensive trout farming.

2. Methods

Data were collected from two different trout farms, one in the lowlands and the other in a mountainous region (900 m of altitude). The first, an intensive trout farm at Levaldigi (Cuneo, NW Italy), is supplied by the waters of the Mellea Canal drawn from the Grana Stream, which is mainly characterised by salmonid fauna (Anonymous, 1992). The facility is composed of a series of concrete raceways. This farm produces salmonids, particularly rainbow trout (*Oncorhynchus mykiss*), with a total biomass of 45 t and a water flow of approximately 1000 l s^{-1}, corresponding to about 22 l t^{-1} s^{-1}. Fish were fed 1–1.5% of live weight twice a day at 8:00 a.m. and 5:00 p.m. The second plant, located in Morgex (Aosta, NW Italy), is characterised by a mixed system including both earthen ponds with a volume of about 1000 m^3 and concrete basins, and is supplied by high altitude spring waters. The earthen ponds had a biomass of 2 t of rainbow trout, and a water flow of 80 l^{-1} s^{-1}, corresponding to about 40 l t^{-1} s^{-1}. Feed was distributed ad libitum by a demand feeder. In both fish farms trout were fed with a commercial diet (10.5% of moisture, 45% of crude protein and 10% of ether extract).

In order to obtain a basic value from the first farm, ammonium content of the inflow water was measured at the beginning and the end of the experiment for one week every 30 min. Then for 29 days (12 days in summer and 17 in autumn), measurements of the outflow waters were taken at the same rate (every 30 min). In the second farm the inflow water was measured for the ammonium for 7 days each 30 min at the beginning and at the end of the test. The outflow waters were measured in the same way for a total of 37 days (from 21

May to 6 July 1998). A total of 2568 measures of ammonium (NH_4^+) were made in the two structures.

Analysis of outflow water was performed by the automated APPLIKON ADI 2013 system connected to a selective ion electrode allowing sampling at fixed times. To maintain high analytic accuracy, the system performed an auto-calibration every 30 analyses.

Data were analysed with one way analysis of variance (ANOVA), using the STATGRAPHICS (1993) statistic package by Manugistic International, Version 6. Same day comparisons were made among measured values every hour (taking into account that the data of two successive measurements were considered as a repetition of the survey for one single hour; in fact, data collected each 0.5 h were averaged for hourly plots), and, within the monitoring period of outflow water, among the daily averages.

No comparison among the data of the two plants was performed because they originated in very different conditions. Graphs of the ammonium content trend, both daily and for the experiment duration, were drawn using average data.

3. Results

Figs. 1–3 show the trends of the values concerning, respectively, both farms relating to the hour, the first plant related to the day and the second farm again related to the day. Ammonium in the inflow water was often close to zero. In the observation periods, the ammonium input averaged 0.15 ± 0.07 in the first farm and it was absent in the second one. In the outflow water ammonium content was (overall average) 0.19 ± 0.09 in the first farm and 0.17 ± 0.02 in the second one. The ANOVA does not reveal peaks in any particular moment of the day in either structure ($F = 0.63$, $P = 97.68\%$ and $F = 0.72$, $P = 92.21\%$); on the contrary, in both cases differences were observed among days. Fig. 2 shows more modest peaks recorded in the waters of the intensive fish farm, with the maximum values of 0.40 mg l^{-1} on 21 June and 0.29 mg l^{-1} on 12 September ($F = 20.63$, $P < 0.001$). Fig. 3 shows remarkable peaks, concerning the Morgex fish farm, that correspond to 0.91 mg l^{-1} on 4 June, to 0.86 mg l^{-1} on 5 June and to 0.36 mg l^{-1} on 19 June ($F = 6.001$, $P < 0.001$).

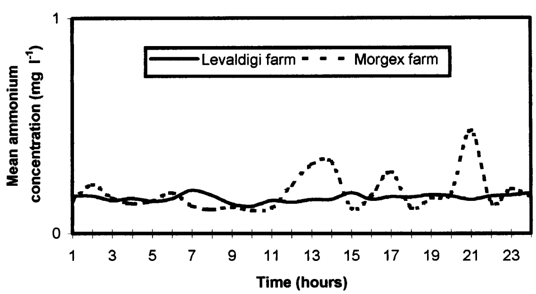

Fig. 1. Daily trend of the ammonium contents in the outflow water of the two examined farms.

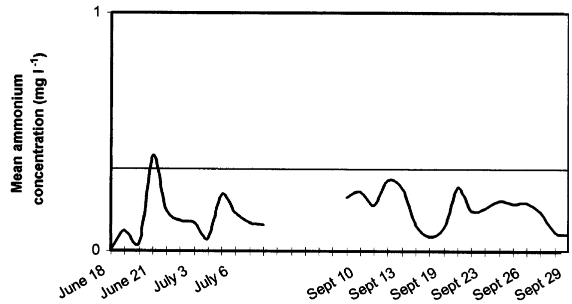

Fig. 2. Ammonium content trend in the outflow water of the Morgex pond; the 0.35 mg l^{-1} ammonium threshold is pointed out as an horizontal row.

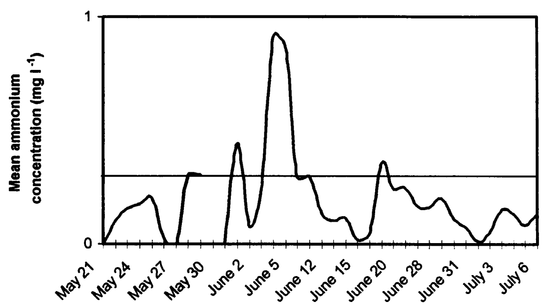

Fig. 3. Ammonium content trend in the outflow water of the Levaldigi trout farm; the 0.35 mg l^{-1} ammonium threshold is pointed out as an horizontal row.

4. Discussion

In previous tests performed on young trout fed commercial diet (given at 1.2% of the fish weight) (Bergero et al., 1996), ammonium excretion was estimated at 12.4 μg per gram of fish h^{-1}. In trout farm conditions, the ammonium excretion was previously found to be 11.4 μg g^{-1} h^{-1} (calculated from data of Sicuro et al. (1997)) and 20.8–26.3 μg g^{-1} h^{-1} (Lanari, 1994); in the present trial, ammonium was excreted at rate of 13.4 μg g^{-1} h^{-1} in the Levaldigi trout farm (previously monitored in the work of Sicuro et al. (1997)) and 27.4 g g^{-1} h^{-1} in the Morgex plant. The latter value may be higher due both to climatic events and the fact that trout were fed ad libitum and uningested food and faecal material decomposed on the surface of the pond's substrate. The peaks recorded in the second plant (Fig. 3) corresponding to 0.912 mg l^{-1} on 4 June, to 0.862 mg l^{-1} on 5 June and to 0.360 mg l^{-1} on 19 June, can be ascribed to exceptional meteorological events (55.4 mm in 1 h on 4 June, 28 and 14 mm in few minutes, respectively) that could have caused an amassment of external water and stirred up the water, so that waste food and faecal material or organic sediments could have been suspended. Therefore these peaks cannot be attributed to ammonium production by trout. On the contrary, the more modest peaks recorded (0.40 mg l^{-1} on 21 June, 0.29 mg l^{-1} on 12 September) (Fig. 2) can be ascribed to the fact that fish were harvested, mainly at the end of the week, for sale. Moreover, some peaks appear in the first hours of the morning (Fig. 1) and during the afternoon in both plants; this phenomenon is more considerable in the Morgex plant (0.19 mg l^{-1} at 5 a.m. and 0.33 mg l^{-1} at 1 p.m.) than in the intensive trout farm (0.20 mg l^{-1} at 6 a.m. and 0.19 mg l^{-1} at 2 p.m.). The early morning peaks are due to a resumption of trout activity after the night with the consequence of the resuspension of physical sediment. In the intensive trout farm, 6 h after the feeding urine secretion and ammonium disposal by gills began as a result of the catabolism (0.15 mg l^{-1} at 11 a.m.). After 8 h intestinal transit of the first meal was completed and faeces production increased, resulting in a maximum concentration of 0.19 mg l^{-1} at 2 p.m. In the pond, the main peaks are due to trout hyperactivity rather than feeding because that occurred on a demand.

Excretion under field condition is estimated at approximately 13 μg g^{-1} h^{-1}. This situation may vary with regard to fish species and size: in gilthead sea bream (*Sparus aurata*) weighing 3, 40 and 90 g, and reared at 24°C, Porter et al. (1987) measured excretion values of up to 43, 15.2 and 14.7 μg g^{-1} h^{-1}, respectively.

Several other studies exist on physiological mechanisms explaining fish nitrogen excretion (Kaushik et al., 1983; Da Silva and Anderson, 1995; Cho and Bureau, 1998). We found high variability in the daily pattern (Fig. 1) probably due to farm management factors. The main ammonium peaks are related to fish movement or fish catching before the sale. It should be taken into account that in our experiment, temperature ranged 8–11°C at the high altitude farm and 10–15°C at the intensive trout farm on the plain, temperatures, which were substantially lower than Porter et al. (1987).

In the Italian trout farms we surveyed, the ammonium content of the outflow was lower than the minimum concentration for zeolite-operated filtration to be effective (0.35 mg l^{-1}): the average value was 0.17 mg l^{-1} at Levaldigi and 0.19 mg l^{-1}at Morgex. Even in the worst cases observed by Lanari (1994), the ammonium content of outflow water (between 0.26 and 0.31 mg l^{-1}) did not reach the required threshold.

Given an excretion rate of 13 μg g^{-1} h^{-1}, no capacity of self-purification and a zero ammonium content of inflow water, it is possible to estimate the flow corresponding to an ammonium content in the outflow of 0.35 mg l^{-1} as 10.3 l t^{-1} s^{-1}, when the temperatures range between 8 and 11°C and food is give at the rate of 1.2% with a crude protein content of about 45%. According to Sedgwick (1990) and Pillay (1992), the typical inflow for an intensive trout farm ranges between 5 and 25 l t^{-1} s^{-1}. In our case, concerning Levaldigi and Morgex, respectively, the inflow was equal to 22 and 40 l t^{-1} s^{-1}.

In Italian productions, even if they cannot be compared with other livestock activities like cattle and pig farming, which produce larger quantities of wastes containing nitrogen, rainbow trout farm are responsible for considerable ammonium discharge into rivers. In conclusion, the use of zeolite filters is advisable in cases where water flow is lower than 10 l $t^{-1}s^{-1}$ (Bergero et al., 1997). In other cases, the quantity of ammonia will be too diluted to be filtered.

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