Acta Biologica Szeged *13*, (3—4), pp. 99—105 (1967)

AMMONIA POISONING IN CARP. 3. THE OXYGEN CONTENT AS A FACTOR INFLUENCING THE TOXIC LIMIT OF AMMONIA

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(Received Oct. 24. 1967)

Introduction

The nitrogen content of the water and mud of fish ponds influences to a great extent the productivity of the pond. It is proved that the amount of ammonia due to the breakdown of proteins or applied as fertilizer is an essential factor in the multiplication of the microorganisms which are important food for the fish. This is why more and more reports deal with the results of the application of nitrogenous fertilizers. But the ammonium influencing the productivity of the pond favourably may, but under certain circumstances, become harmful and cause rapid perishing of the fish (Woker, 1949; Schäperclaus, 1952, 1957). Poisoning caused by so-called free ammonia can occur understandably first of all in fish ponds established on alkaline soils and in ponds with alkaline water where it may cause sterility of shorter or longer duration. A good example of the latter cause is the pond Kunfehértó near Kiskunhalas, between Tisza and Danube. Only 3—4 years ago there was no fish life at all in this pond. It was easy to find the cause of this, because at that time the water of the pond was extremely alkaline. Its pH value varied between 10,1—10,3 and its ammonium content between 0,5—0,7 mg, free ammonia 0,48 mg/l. Populating the pond with carp did not produce the expected result either. At the beginning of the warm weather when the temperature of the shallow water soon reached 20—25 C° the populated fish colony perished. This year (1967) however, the abundant spring rainfall raised the level of the pond by 100 cm, and in consequence of the greater dilution the pH value fell to 8,3. Perishing of the fish did not occur in spite of the long-lasting warm weather and the population developed undisturbed. It is hoped that there will be no trouble in the future until the water of the pond regains its former concentration in a drier period.

Material and method

The experiments were carried out at the State Fish Farm of Szeged and the investigations also in ohetr fish ponds with alkaline water where mass decay of fish due to ammonia occurred.

The examinations were carried out by Prof. Winkler's methods well-known in limnology (Maucha, 1930).

Experimental

We have stated that in our ponds with very alkaline water the pH value of which is over 9 the presence of even a very small, less than one mg/l ammonia is enough to cause perishing of the fish. While the water of the ponds is neutral or nearly so, even a larger amount of 10—15 mg/l ammonium ions does not constitute a danger. In the alkaline waters, however, the ammonium transforms into free ammonia which being a poison may also poison the fish. Besides alkalinity the longlasting warm temperature is also an important factor in the transformation because at a higher temperature the formation of free ammonia is also more intensive. For instance in water with pH 8,5 and a temperature of 17 C° only 10 per cent of the ammonium transforms into free ammonia while at 25 C° in the same water 15 per cent and at 30 C° 20 per cent. This means that the longlasting summer heat, partly by increasing the alkalinity, partly by raising the temperature of water, increases the danger of fish as an effect of ammonia and this may even occur regularly.

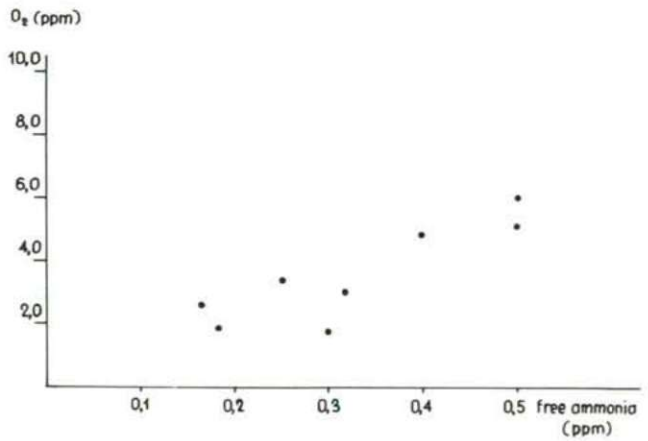

Fig. 1. Oxygen content of the water at time of the fish decays caused by ammonia.

In order to determine the toxic limit value of the free ammonia we conducted a series of experiments at the Szeged State Fish Farm in previous years. In the course of these experiments it was ascertained that the lethal limit value of the free ammonia is around 0,5 mg/l in the case of the carp (Vámos and Tasnádi, 1961; Vámos, 1963). These experiments, however, were carried out not in original fish pond

water but in water from a bored well containing 5—6 mg/l of oxygen. During these experiments also the characteristic reactions provoked by the ammonia were noted. In the following years, however, we learned several cases of rapid fish decay caused by ammonia in which the amount of so-called free ammonia was below 0,5 mg/l. Such decay of fish occurred most recently on the 7th of August 1967 in the pond No. X. of the Szeged Fish Farm where at the beginning of the decay the mother carps as well as smaller fish swam about in the surface layer of the water and flapping in vertical direction they jumped out of the water. This perishing damaged especially the stock of mother carp. The oxygen content of the water was only 1,4 mg/l, the ammonium content 0,8 mg/l, the temperature of the water 25 C°, the pH 9,1 i.e. the free ammonia content may have been around 0,3 mg/l.

In the cases of perishing of fish that came to our notice we made determinations of oxygen, ammonia and pH. Fig. 1 shows the results. From the results shown in the figure we can conclude that the toxicity of the free ammonia determined by the three factors (pH-value, NH_4^+-content and temperature) becomes less with the decrease of the oxygen content. Perishing of fish occurred also when the amount of free ammonia was only 0,2 mg/l. This means that in insufficient oxygen supply of the fish the toxic limit value of ammonia is diminished.

A further task was to find out what could be the cause of the marked decrease of oxygen, and the cause of the fact that on a sunny afternoon when the algae assimilate undisturbed and produce oxygen the water contained only 1—2 mg of oxygen per litre. The already well-known restlessness of the fish indicated the danger definitely where else 10—12 mg/l of oxygen was found before 2—3 hours.

Investigating such cases of damage so far, as Veszprémi (1964) has also stated, a decrease in atmosperic pressure has always been involved, i.e. in all such cases of fish decay a decrease was observed in the atmospheric pressure. So it was also with the last cases examined in Szeged. The atmospheric pressure changes in the period of the perishing are shown in Fig. 2. The causal relation between the decrease of the atmospheric pressure and the decrease of the oxygen content of the water can be explained as follows.

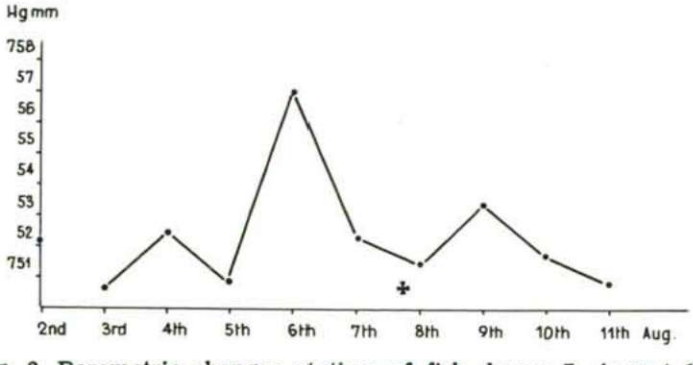

Fig. 2. Barometric changes at time of fish decay: 7. August 1967.

The role of the decrease of atmospheric pressure

It is well known that the decomposition of the organic matter in the mud is accompanied by intensive gas production. The gases form according to the evidence of our model experiments, small caverns and accumulate. The main factors of the gas formation of the mud are the temperature and the amount of organic matter to be decomposed. In fish ponds with thin water cover the gas production is more intensive because of a greater degree of warming.

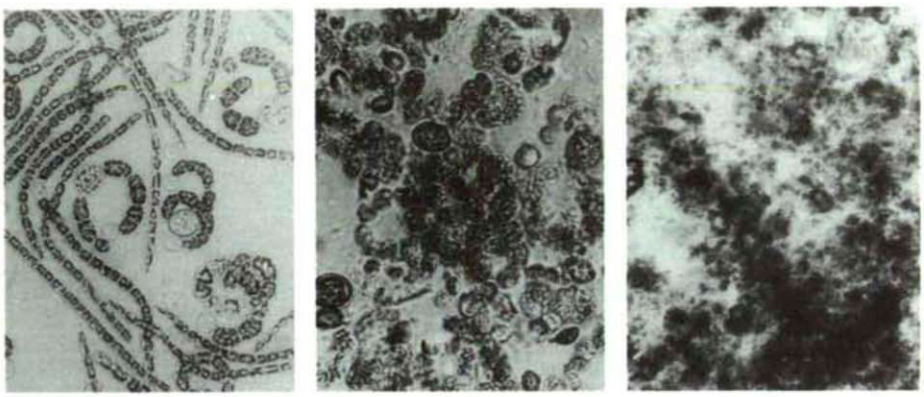

Fig. 3. Disintegration of the algae at the time of fish decay.

When the atmospheric pressure falls the air pressure on the water layer decreases and the gas bubbles appear on the surface of the water. The rising gas bubbles carry mud particles a large part of which is of organic colloids. Then the turbidity of the water increases, and the facultative anaerobic bacteria doing the work of decomposition of the particles begin to multiply rapidly in the water under more favourable conditions. The multiplication depends on the better oxygen supply. The higher temperature in the mud is 18—20 C°, however that of the surface layer of the water is 25—30 C°. It was be stated that the number of the bacteria in 1 ml of water can in a few hours, grow several hundred times. The multiplying bacteria may form a continuous film on the surface of the water. The multiplication of the bacteria was proved using Petri dishes and dark fields. The increased oxygen consumption of the bacteria has an unfavourable effect on the algae. If the amount of the oxygen sinks below the quantity necessary to the normal respiration of the algae this condition may disturb the assimilation, i.e. the oxygen production of the algae. This is why we could measure 1,3—1,7 mg/l oxygen content in glaring sunlight in the early afternoon hours even though the number of algae was 210—340 million. The algae with disturbed metabolism may later be attacked by bacteria. Thereby begins the massive dying and disintegration of the algae.

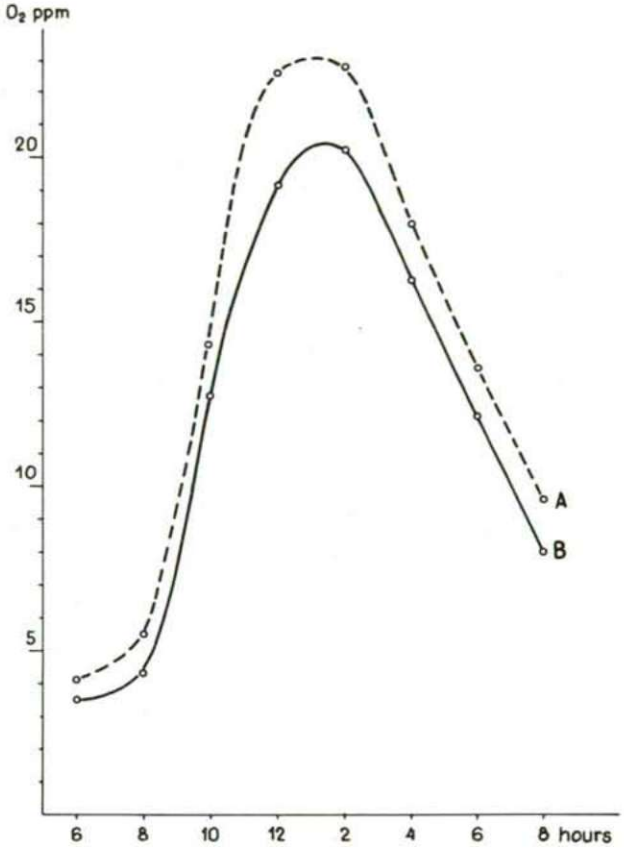

Fig. 4. Changes of oxygen content on a sunny day. A = without mud, B = with mud.

In order to find out whether the bacterium flora of the mud influences the oxygen content of the water we made the following model experiment. For the experiment we used two six litre glass containers. On the bottom of one 1,0 kg of garden soil was put, its organic matter content was 5,6 per cent. Then into both 5 litres of the same kind of pond water was poured in which the original number of algae was 140 million/l. The containers were kept in a glasshouse. After three days, oxygen determinations were made in every hour. The results are shown in Fig. 4. and Fig. 5. As it can be seen from the figure, the bacteria living in the mud and decomposing the organic materials, as consumers, play a part in the reduction of the oxygen content of the water. The oxygen content in the jar containing mud was smaller than in that without mud.

Fighting down ammonia poisoning

After finding out the above facts we could think of the following possibilities to prevent ammonia poisoning:

1. Increasing the oxygen content of the water.
2. Decreasing the high pH-value.
3. Binding the free ammonia.

It is possible to increase the oxygen content if we have a water supply of sufficient quantity and suitable quality at our disposal.

Unfavourably high pH value may be reduced partly by dilution with water in which the pH-value is low, as described above, and partly by chemical treatment. In the latter procedure the application of cheap sulphuric acid may first of all come into consideration.

To bind the poisonous free ammonia the use of cupric sulphate has so far proved the most successful. The cupric sulphate was dissolved in the boat and from there poured out into the pond. As every cupric ion can bind 4 molecules of ammonium hydroxide, a relatively small amount of cupric sulphate is sufficient for binding the ammonia and is not dangerous to the fish either. Practice justified our theoretical calculations. 2,5 kg of cupric sulphate calculated for one hectare and 60 cm depth, proved sufficient for binding 0,2 mg/l of free ammonia.

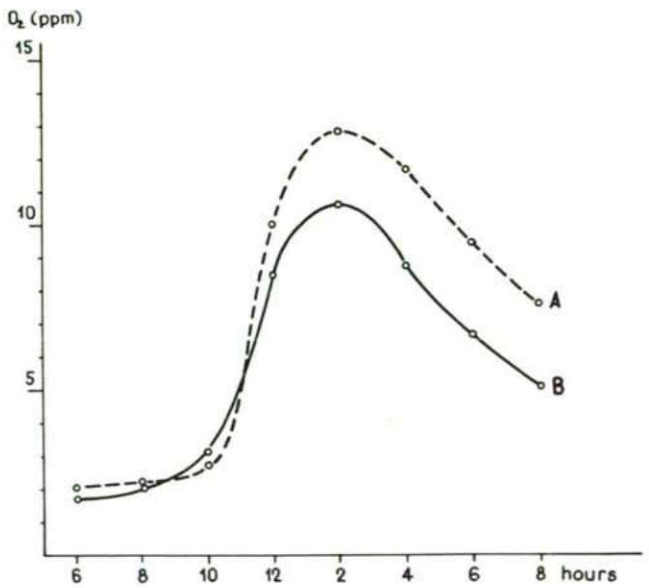

Fig. 5. Changes of oxygen content on a day with inconstant weather. A = without mud, B = with mud.

Summary

The authors have conducted experiments in order to determine the toxic limit of free ammonia and to known the symptoms caused by it. The experiments were made with carp in tap water. The toxic limit was 0,5 mg/l of free ammonia. In recent years several such cases of mass decay of fish due to ammonia occurred in which the toxic limit was below 0,5 mg/l. In the course investigating the cases of fish decay a relation was found between the amount of toxic free ammonia and the oxygen content of the water. It was stated that with the reduction of the oxygen content the toxic value of the free ammonia also decreases.

The application of dissolved cupric sulphate proved succesful against the toxic effect.

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