Water Quality After Application of Pig Slurry

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1. Introduction

Pig slurry is a complex organic-mineral fertilizer with high fertilising efficiency and it is comparable with farmyard manure. The pig house with excremental ending and subsequent use of slurry is very popular in agriculturally advanced countries because of economic efficiency, work culture and hygiene. Pig house is operationally by 30 - 40 % cheaper than using bedding. Properly made and treated slurry means a significant source of organic matter, nutrients, bacteria and stimulators which if correctly applied, increase fertility and provide a significant cost saving. These slurry nutrients are easily usable for phytoplankton. Nitrogen is found mainly in inorganic form (50 – 60%), just 10% is nitrate and rest forms organic nitrogen. Phosphorus is bound to organic matter and potassium is included in the urine. Chemically the high fertilising efficiency of slurry depends on C:N ratio, which is usually 4-8:1. This ratio affects the mineralization of organic matter, release of N from organic fixation and energy utilization for multiplication of microorganisms. Composition of the slurry is in the Table No.1.

Dry matter	**pH**	**Conductivity**	**ANC**	**COD_{Cr}**	**Ca^{2+}**
%		mS.m^{-1}	mmol.l^{-1}	g.l^{-1}	mg.l^{-1}
1.4 - 7.5	6.21 – 7.90	1918 - 2715	179 - 227	16.0 – 18.5	300 - 1300
TP	**TN**	**$N\text{-}NH_4$**	**$N\text{-}NO_3$**	**$N\text{-}NO_2$**	**K^+**
mg.l^{-1}	mg.l^{-1}	mg.l^{-1}	mg.l^{-1}	mg.l^{-1}	mg.l^{-1}
33 - 2200	1440 - 6000	1000 - 4348	16.9 – 36.2	1.28 – 3.34	315 - 7686

Table 1. Values of physical and chemical parameters in pig slurry applied into ponds. (min-max interval, amended by more authors), ANC - acid neutralization capacity, COD - chemical oxygen demand, TP - total phosphorus, TN – total nitrogen

An additional fertilizer in intensively managed fish-ponds usually does not mean that significant increase of fish production as observed in nutrient-poor waters. Moreover, excessive application of fertilizer may lead to environmental pollution and sanitary problems. Fairly high fish production can be achieved by organic fertilizers. The application of pig slurry to ponds as a fertilizer is widely used in many countries in order to increase plankton production and fish growth. That’s why manuring is considered to be a cheap way to increase carp production in the pond. Some fish species also feed directly upon these waste, which is enriched by microorganisms with high protein value. Further, different types of manure can be also added into the low-level protein feeds. The type of pig slurry, quality, quantity and the season affects water quality and production of the pond and finally on well-being and growth of fish. Additionally, recycling of pig slurry could be interesting for fish farming in order to reduce the impact of intensive pig farming on environment.

Pig slurry applied to ponds as organic fertilizer necessary needs a decomposition before their nutritional contents are released, assimilated and utilized by plankton. The nutrient content of pig slurry may vary with time, and nutrient availability to phytoplankton growth remains unclear. The rate of nutrients released from animal manure is an important factor to regulate the frequency and amount of manure required to fertilize fish ponds. Pig slurry is destined mainly for refilling of carbon into water and modification of proportion basic biogenic elements (C, N, P). During the water treatment by slurry the amount of carbon dioxide in pond was relatively higher (Fig. 1). After the last application of pig slurry in early may in 2001 alkalinity increased and value of pH decreased which caused a significant increased in values of TIC due to the weather conditions and lower intensity of photosynthesis. On the other hand another TIC value decrease occurred in 2002 (at the end of March) due to higher phytoplankton development. This expansion decreased carbonate content, alkalinity and increased pH.

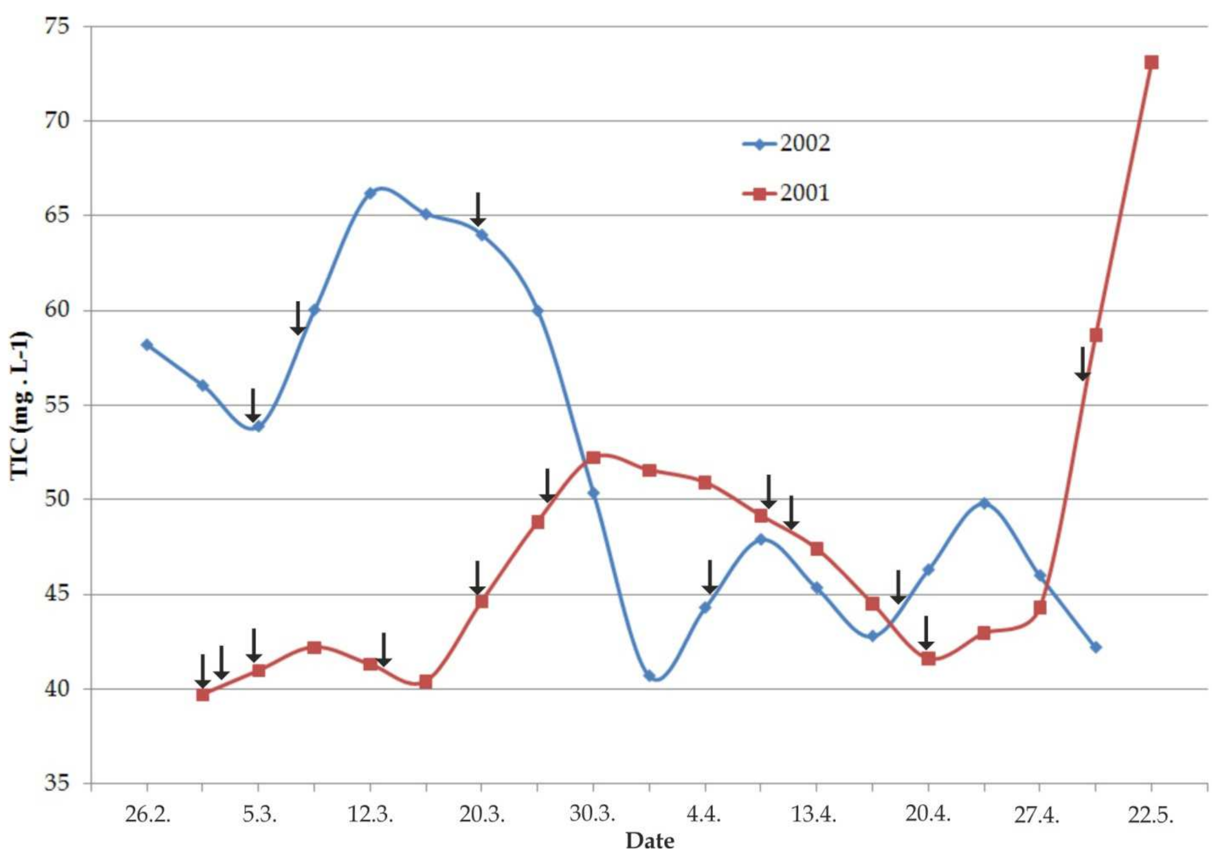

Fig. 1. Variation of total inorganic carbon (TIC) during application of pig slurry into the pond. Level of total doses 16 kg . m^{-2} in the year 2001 and 2002. (Arrows indicate term of pig slurry application)

Negative balance of carbon dioxide in ponds, evoked by plants assimilation at high content of nutrients in water, leads to high values of pH that could be the cause of fish gill necrosis. When using the pig slurry for ponds treatment, some bacteria and other microorganisms are also required to commence decomposition of the slurry and they have positive influence on zooplankton development, especially cladocerans. Bacteria that come into the water environment together with pig slurry are also a direct food source of zooplankton.

2. Fertilizer management

The amount of applied pig slurry depends on natural production of the pond, altitude, depth, control of the water inflow, fish stock etc. Due to the fish stock safety it is better to apply a slurry before vegetation season when a lower water temperature reduces the risk of oxygen deficit (Olah et al. 1986). Abnormal phytoplankton development is reduced in cold weather us well, which is associated with low pH and limited effect of toxic ammonia nitrogen on aquatic organisms. To maintain the stability of the pond ecosystem is not suitable to use a slurry in case of abnormal growth of submerged vegetation or water bloom, when water transparency is less than 40 cm (measured by Secchi disc), in case of abundance of basic nutrients or zooplankton overgrowth. For stability of the physical – chemical parameters it is necessary to properly organize an areal distribution, dose and interval of slurry application (Wohlfarth and Schroeder, 1979).

Knud-Hansen and Batterson (1994) tested four fertilization frequencies (daily, twice per week, weekly, and once every two weeks). The study showed that fertilization frequency had a strong linear relationship to net primary production. Zhu et al. (1990) showed that applying pig slurry daily produced higher yields of fish than five or seven day application. Garg and Bhatnagar (2000) also stated that fertilization frequency influenced fish yield. Variation of manuring frequency often depended on convenience, labour saving, the need to dispose the waste and availability of fertilizer, rather than increasing of the productivity of pond ecosystem. Under the experimental conditions it appears that the frequency of fertilizers application to maintain optimum primary production, should be every eight to ten days (Kestemont, 1995**;** Kumar et al. 2004). Planning of the fertilization frequencies should predict the time frame between each treatment which has got the potential of production enhancing and also reducing costs. There is a factor to be considered when fertilizing with manure: possibility of de-oxygenation of the water, which is quite likely when large quantities of manure are added at a time.

Fertilizers batching at doses 0.5-2.0 $kg.m^{-2}$ of ponds water increased live weight gain of fish about 30-450 $kg.ha^{-1}$ without supplementary feeding of fish (Hartman et al., 1973; Dhawan and Kaur, 2002). The effect of organic fertilizers from animal breeding farm is higher in ponds with polycultural fish stock where is the highest weight-gain per fish (Buck et al., 1978; Dhawan and Kaur, 2002; Zoccarato et al., 1995). Woynarovich (1976) reported pig slurry conversion of 3–5 % into fish body mass. In the case of polycultural fish stock is ratio higher than in the case of carp monoculture (Prinsloo and Schoonbee, 1984). Zhu et al. (1990) mentioned demand of 8.3 kg dry weight of pig slurry to weight-gain of 1 kg fish flesh. The maximal increases in fish production from fertilizers is especially in the tropics, on average, 4 kg fresh pig slurry can produce 1 kg of fish (Biro, 1995). Variously high doses of pig slurry were tried in ponds experiments. Pig slurry doses around 15-16 $kg.m^{-2}$ were acceptable but they should be applied mainly before vegetation season, when a water temperature is lower (Kopp et al. 2008). Ponds have had concentrate polycultural fish stock during the experiment and fish were intensively fed by cereals. The increased production of the pond supported by pig slurry was 270–630 $kg.ha^{-1}$. In these experiments the fish production in the high fertilized ponds appears the same values that obtained other researchers.

3. Autotrophs and heterotrophs

A successful fertilization programme in ponds should develop adequate amounts of food organisms for fish. Organic fertilizer (e.g. pig slurry) has been used to stimulate the development of heterotrophs (bacteria), autotrophs (algae) and other food organisms (zooplankton) to increase fish production in ponds (Schroeder, 1978). Bacteria and algae are important food organism for the herbivorous zooplankton that is consumed by many fish species (Wylie and Currie, 1991). In additional to the bulk of photosynthetic production passing directly to higher trophic levels, in some cases more than 50% of primary production is derived from a microbial loop (Hepher, 1992; Qin et al. 1995; Biro, 1995). Bacterivorous flagellates are a key link in the microbial loop to transfer organic carbon from bacteria to zooplankton and fish (Sanders and Porter, 1990). An increasing amount of evidence shows that bacteria together with algae provide an efficient energy pathway from low trophic levels to zooplankton. In natural waters, bacterial production can be enhanced by increasing organic matter loading, but the excessive application of organic matter into fish ponds can reduce dissolved oxygen and can cause fish kills (Qin and Culver, 1992). It is crucial to keep the amounts of organic fertilizer within limits such that adequate amount of heterotrophic organisms are produced yet without oxygen depletion occurring.

The reduction of algal biomass through grazing of zooplankton may indirectly regulate the amount of substrate available for bacterial growth. Bacterial and algal abundances were negatively correlated in fertilized ponds. This may have resulted from the die-off of algae that released dissolved organic compounds into the water, which in turn stimulated bacterial growth (Qin et al. 1995). In natural lakes, zooplankton populations crash after the decline of algae. In ponds, the zooplankton population might be sustained after algal decline by adding organic fertilizer to promote bacterial growth. Thus a direct input of pig slurry could increase bacterial productivity, which in turn could serve as a valuable food source for zooplankton.

When organic fertilizers are applied to ponds the first link of the food chain is heavily influenced, principally phytoplankton (Dhawan and Toor, 1989). High doses of pig slurry supported typically groups of phytoplankton favour higher amount of organic matter. Dominant algal genera often are *Cryptomonas*, *Chroomonas*, *Monodus* and *Euglena*. Generally also are occurred small genera of centric diatoms (*Stephanodiscus*, *Cyclotella*) and chlorococcal green algae (*Desmodesmus*, *Scenedesmus*, *Chlorella*, *Monoraphidium*). Cyanobacteria usually are not dominant groups in fertilizing ponds. High nitrogen to phosphorus ratios non favour dominance by cyanobacteria in pond phytoplankton (Smith, 1983). Typically genus *Microcystis*, *Aphanizomenon* and *Dolichospermum* in many fish-ponds and eutrophic lakes, cyanobacteria constitute the greater part of the summer phytoplankton biomass, causing regular water blooms and massive fish mortalities by depletion of oxygen after the bloom collapsed are not common in fertilizing ponds. Most often are occurred genus of cyanobacteria *Pseudanabaena*, *Planktothrix* and *Aphanocapsa* (Kopp and Sukop, 2003; Qui et al. 1995; Terziyski et al. 2007). Higher fish stock, sufficiency of carbon dioxide, suitable ratio of nutrients (C, N, P) in ponds after applications of pig slurry handicapped cyanobacteria forming water blooms. Cyanobacteria are of poor food value to zooplankton, their large size making them inaccessible to the filter-feeding entomostraca. Even the substances produced by many species of cyanobacteria are toxic to aquatic plants and animals (Sevrin-Reyssac and Pletikosic, 1990).

In ponds treated with slurry they have positive influence on zooplankton development. Though, the results of the experiments indicate that the fish stock with its predaceous pressure exerts a more significant influence on zooplankton than application of the slurry. Nevertheless, the initial development of large species of cladocerans was in ponds fertilized by slurry the more intensive to compare with control ponds (Sukop, 1980). When comparing different treatments, zooplankton was significantly higher in ponds manured with pig slurry. Higher zooplankton density as a result of manuring has also been reported in ponds receiving pig dung (Govind et al. 1978; Dhawan and Kaur, 2002). Dominant of zooplankton genera often are Copepoda (*Cyclops*, *Thermocyclops* and *Acanthocyclops*), nauplius and copepodits stages, small and middle genus of cladocerans (*Bosmina, Chydorus, Moina* and *Daphnia*) and Rotatoria (*Brachionus, Keratella* and *Asplanchna*) (Kopp and Sukop, 2003; Terziyski et al. 2007). Development biomass of planktonic communities in pond after pig slurry application is demonstrated in Figures 2-4.

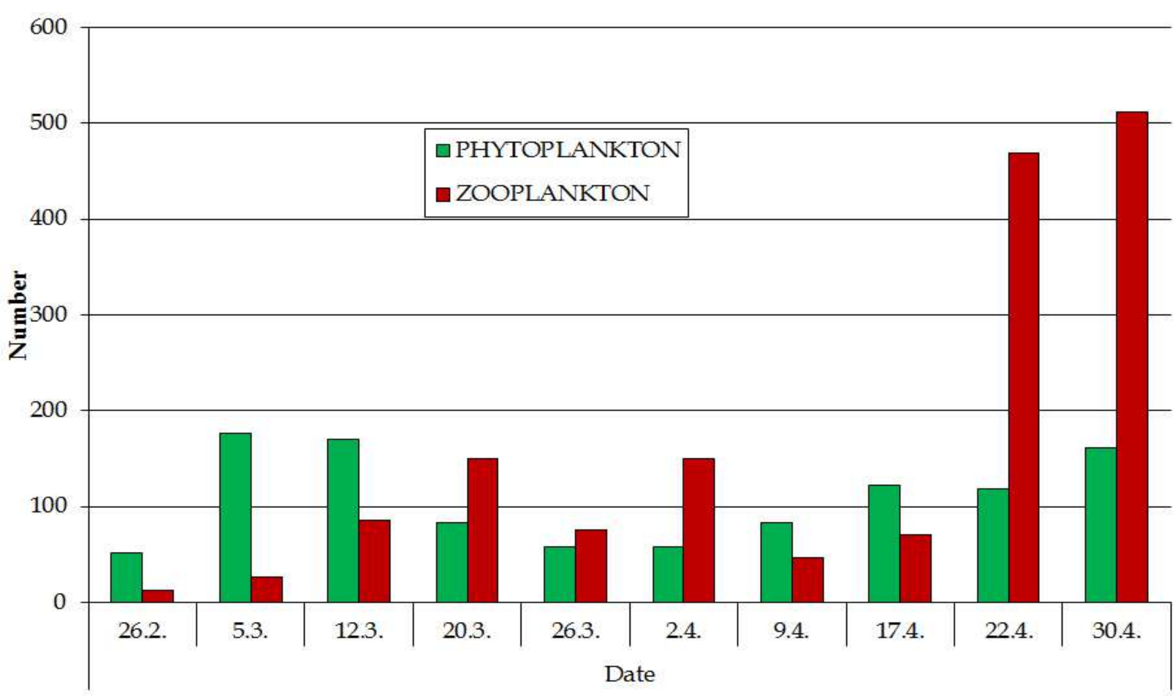

Fig. 2. Quantity of phytoplankton (individuals 10^3 . mL^{-1}) and zooplankton (individuals . L^{-1}) in pond during applications of pig slurry in total doses 16 kg . m^{-2}. (Application began at 5.3.)

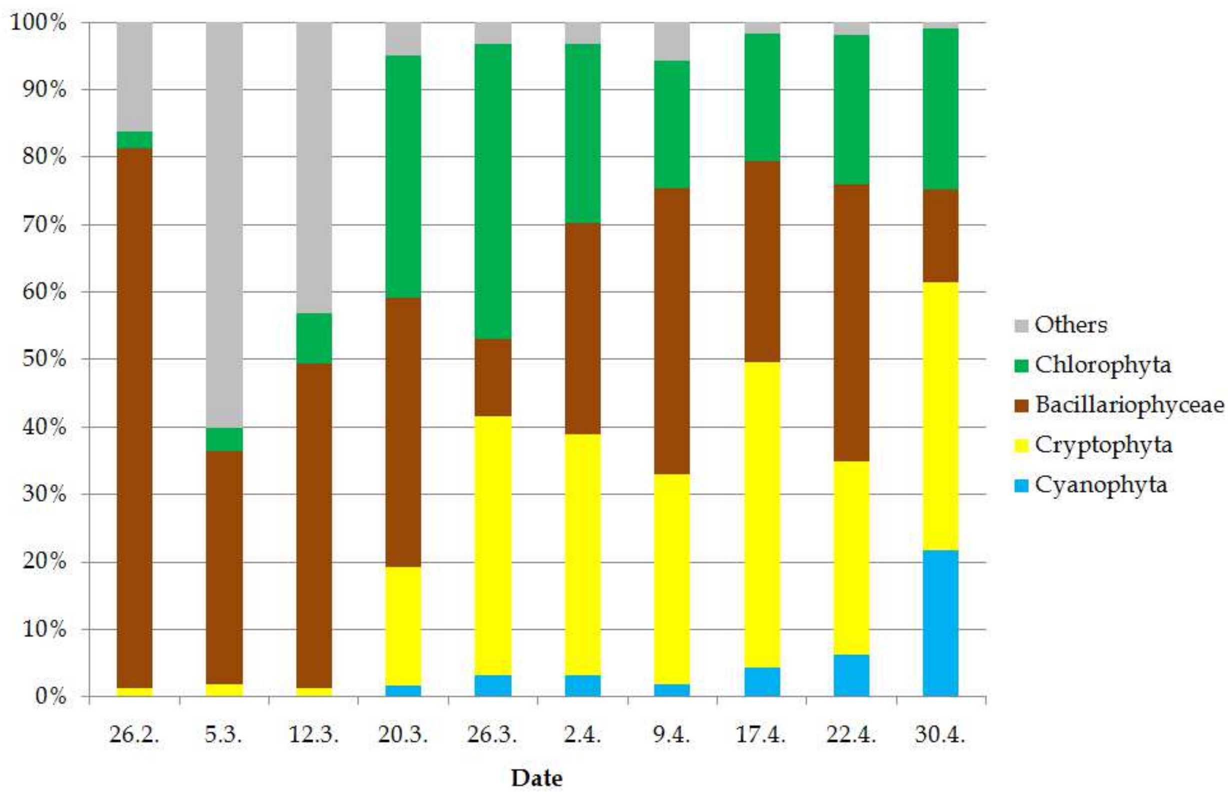

Fig. 3. Quantity of main groups of phytoplankton in pond during applications of pig slurry in total doses 16 kg . m^{-2}. (Application began at 5.3.)

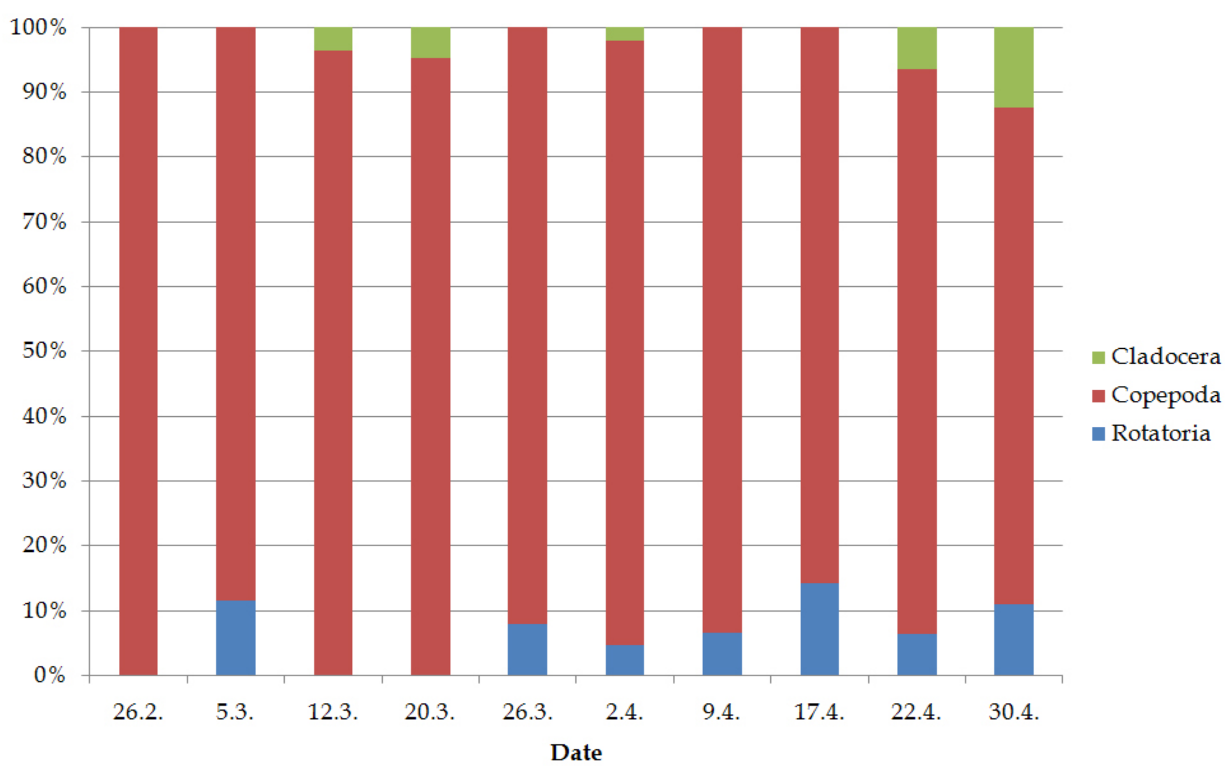

Fig. 4. Quantity of main groups of zooplankton in pond during applications of pig slurry in total doses 16 kg . m^{-2}. (Application began at 5.3.)

4. Organic matter

Application of pig slurry to the water environment is bringing a huge amount of organic matter. Compare to other organic fertiliser the pig slurry has got lower content of organic substances, usually not exceed 10% in total (Hennig and Poppe, 1975). Majority of organic substances in pig slurry is biodegradable and relatively quickly mineralized by microorganisms. During the higher doses of manure to the fish ponds is important to control oxygen content which is intensively consumed due the decomposition of organic matter (Kopp et al. 2008). Application of organic fertiliser into the pond is immediately reflected in the increase of biological oxygen demand (BOD) and chemical oxygen demand (COD). As shows Figures 5 and 6, values change in wide range depending on dosage and elapsed time since last application. Important role for degradation of organic matter plays mainly water temperature and amount of microorganisms that decompose present organic matter. Significant reduction of COD and BOD observed during pig slurry application (Fig. 5 and 6) were mainly caused by changes of water temperature and the rate of degradation of organic substances. In water unloaded organic substances is value of BOD under 8 mg . L^{-1} and COD under 35 mg . L^{-1}, due to manuring could be these values doubled (Zalud, 2008). Just one month after last application of pig slurry into the pond are decreasing values of organic load to a level comparable with ponds without fertilization (Kopp et al. 2008).

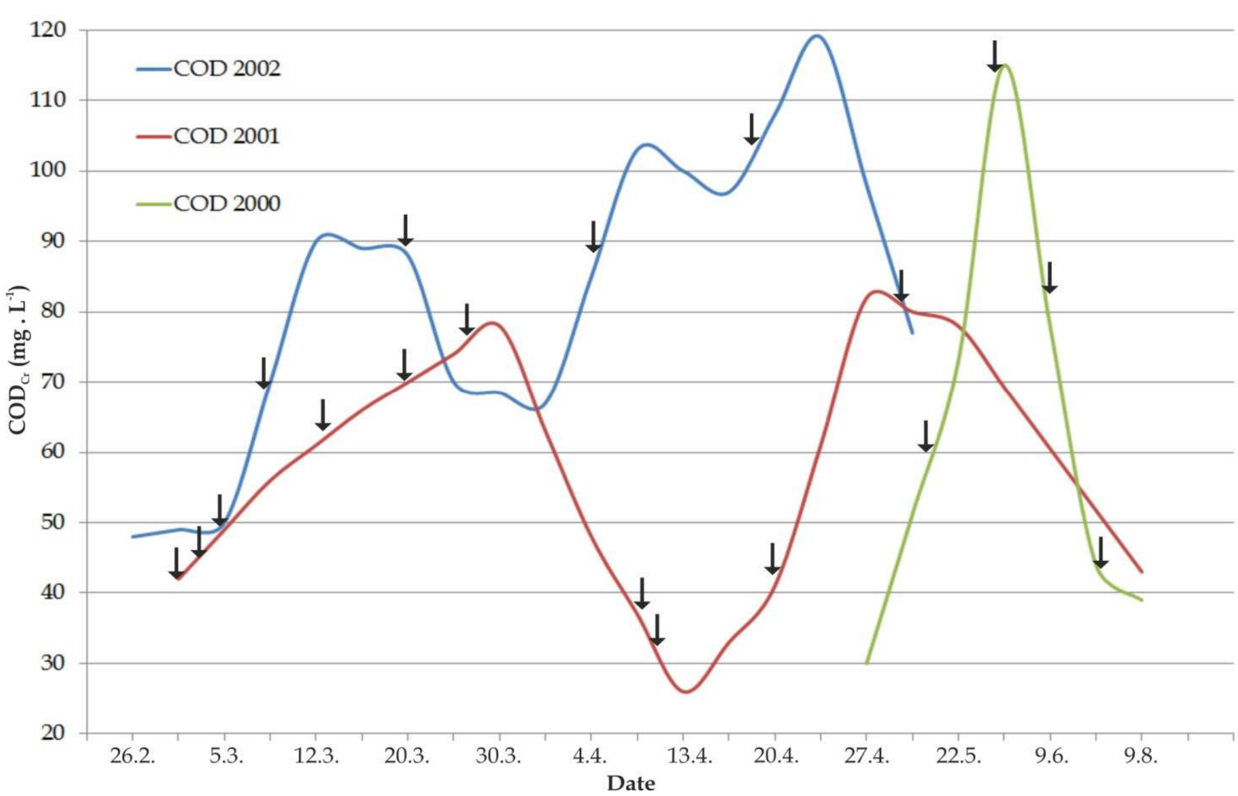

Fig. 5. Variation values of chemical oxygen demand (COD_{Cr}) during application of pig slurry into the ponds. Level of total doses 16 kg . m^{-2} (2001, 2002) and 0.10 kg . m^{-2} (2000). (Arrows indicate term of application of pig slurry)

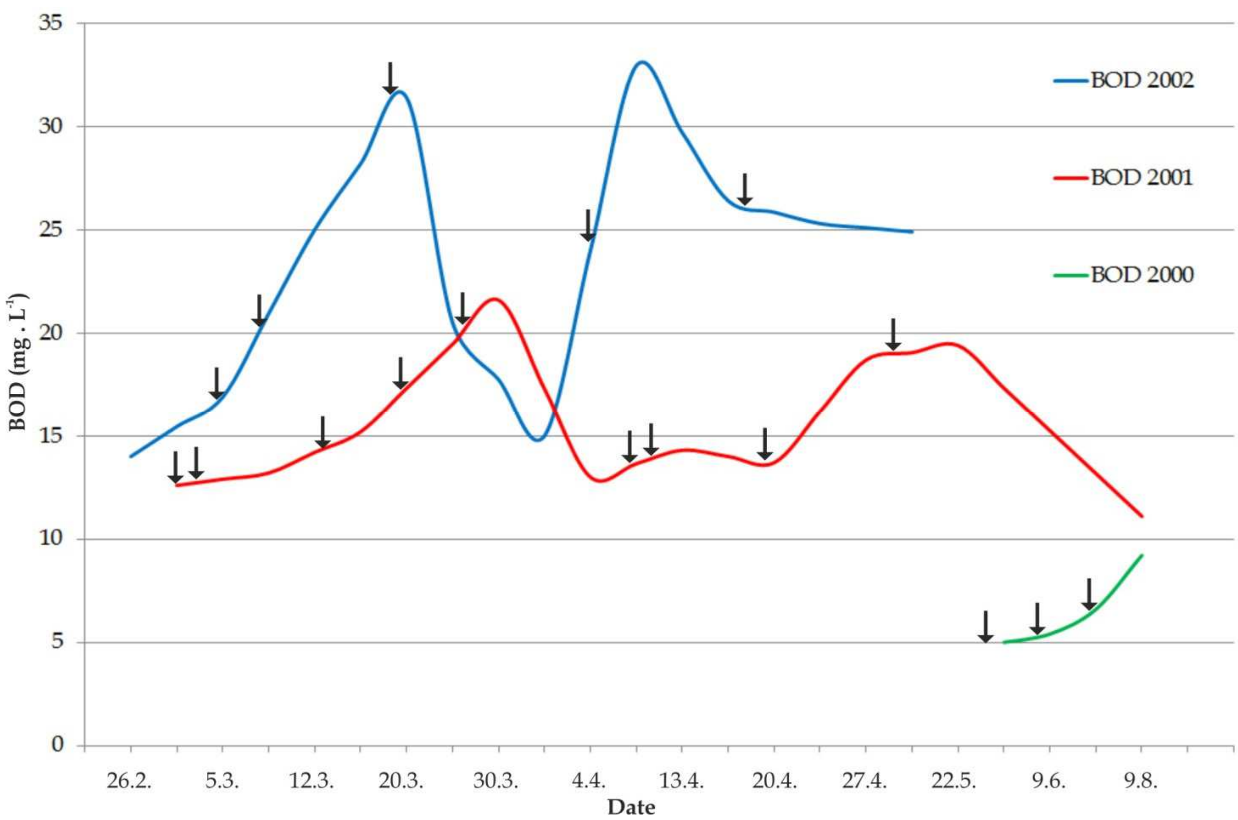

Fig. 6. Variation values of biological oxygen demand (BOD_5) during application of pig slurry into the ponds. Level of total doses 16 kg . m^{-2} (2001, 2002) and 0.10 kg . m^{-2} (2000). (Arrows indicate term of application of pig slurry)

5. Chlorophyll-a

Chlorophyll content in surface water is an important indicator of trophic level and one of the most often used indicators of biomass of primary producers. Concentration of chlorophyll in clear water usually does not exceed 10 µg . L^{-1}. In fish ponds and water reservoirs are values during the vegetation season in the tens to hundreds µg . L^{-1}. In case of hypertrophic water area with massive cyanobacteria water bloom could be chlorophyll content over thousands µg . L^{-1} (Zalud, 2008).

The average amount of phytoplankton in ponds, expressed as chlorophyll-a concentration, has increased since 1960s from 30-35 µg . L^{-1} to 140-150 µg . L^{-1} till then 1990s. The impact of organic fertilization on increasing values of chlorophyll-a is well documented (Potužák et al., 2007). The application of organic fertilizer at regular intervals caused regular fluctuations of chlorophyll-a in the ponds.

After the application of pig slurry is increasing phytoplankton biomass as well as content of chlorophyll-a. The subsequent increase of zooplankton is lowering phytoplankton biomass by predation and also cause decreasing of chlorophyll–a. Fluctuations in value of chlorophyll–a during the pig slurry application is shows in Figure 7. Despite bigger doses of pig slurry are values of chlorophyll–a not so high. High stock of carp fish is increasing inorganic water turbidity by the feed pressure on the ponds bottom, decreasing transparency and limiting abnormal phytoplankton development due to inadequate lighting conditions. Lower water temperature and predation of zooplankton is limiting phytoplankton as well. (Kopp et al. 2008).

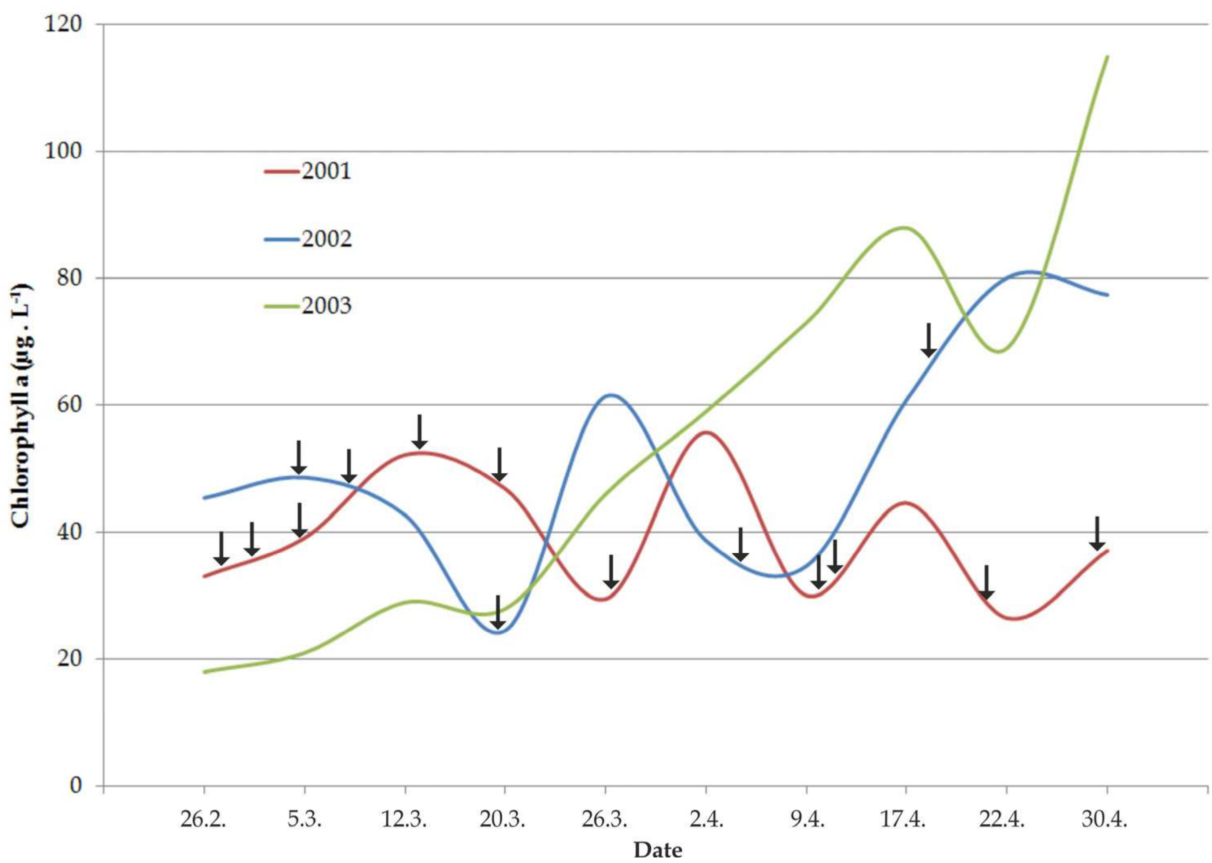

Fig. 7. Variation values of chlorophyll-a during the application of pig slurry into the pond. Level of total doses 16 kg . m^{-2} (2001, 2002) and without application of pig slurry (2003). (Application began at 28.2. in the year 2001 and 5.3. in the year 2002 respectively)

6. Dissolved oxygen

Dissolved oxygen concentrations in the ponds are most affected by phytoplankton biomass. Greater oxygen production and consumption occurs in ponds with higher phytoplankton biomass. The use of pig slurry increased the biological oxygen demand in ponds and could result in periods of low dissolved oxygen levels. The aerobic decomposition of organic matter by bacteria is an important drain of oxygen supplies in ponds. When added to ponds organic fertilizers exert an oxygen demand and an excessive application may result in depletion of dissolved oxygen (Schroeder, 1974, 1975). Qin et al., (1995) observed that dissolved oxygen in fish ponds with organic fertilizer was lower than in those without organic fertilizer, and dissolved oxygen in enclosures decreased with the increase of organic fertilizer loading.

Oxygen consumption in pond is regulated by biological and sediment oxygen demand and fish. In intensive fish aquaculture, BOD reached 0.29 mg O_2 . L^{-1} . h^{-1} in Israel (Schroeder, 1975), and 0.14 mg O_2 . L^{-1} . h^{-1} in fertilized ponds in USA (Boyd 1973). Qin et al., (1995) described that the BOD value varied with organic matter loadings and temperature. The BOD of fertilized ponds water varied from 0.19 to 0.34 mg O_2 . L^{-1} . h^{-1}. Similar results described Kopp et al. (2008) from Czech Republic, when the BOD value varied from 0.12 to 0.34 mg O_2 . L^{-1} . h^{-1} in pond during application high doses of pig slurry (Figure 8). It is certain that excessive organic fertilizer inputs can be a major factor depleting oxygen in ponds, especially during the clear-water phase when algae are less abundant (Qin and Culver, 1992). Analogous situation can be turn up during application of organic fertilizers, when higher development of zooplankton reduced the quantity of phytoplankton and dissolved oxygen concentrations declined. At high temperatures a heavy organic fertilizer application should also be avoided, otherwise a fish kill is likely to occur due to oxygen depletion.

On the second hand Dhawan and Kaur, (2002) reported that pig slurry even at higher dose (36 t . ha^{-1} . yr^{-1}) had no adverse effect on the dissolved oxygen content, which is an important parameter for the survival and growth of fish.

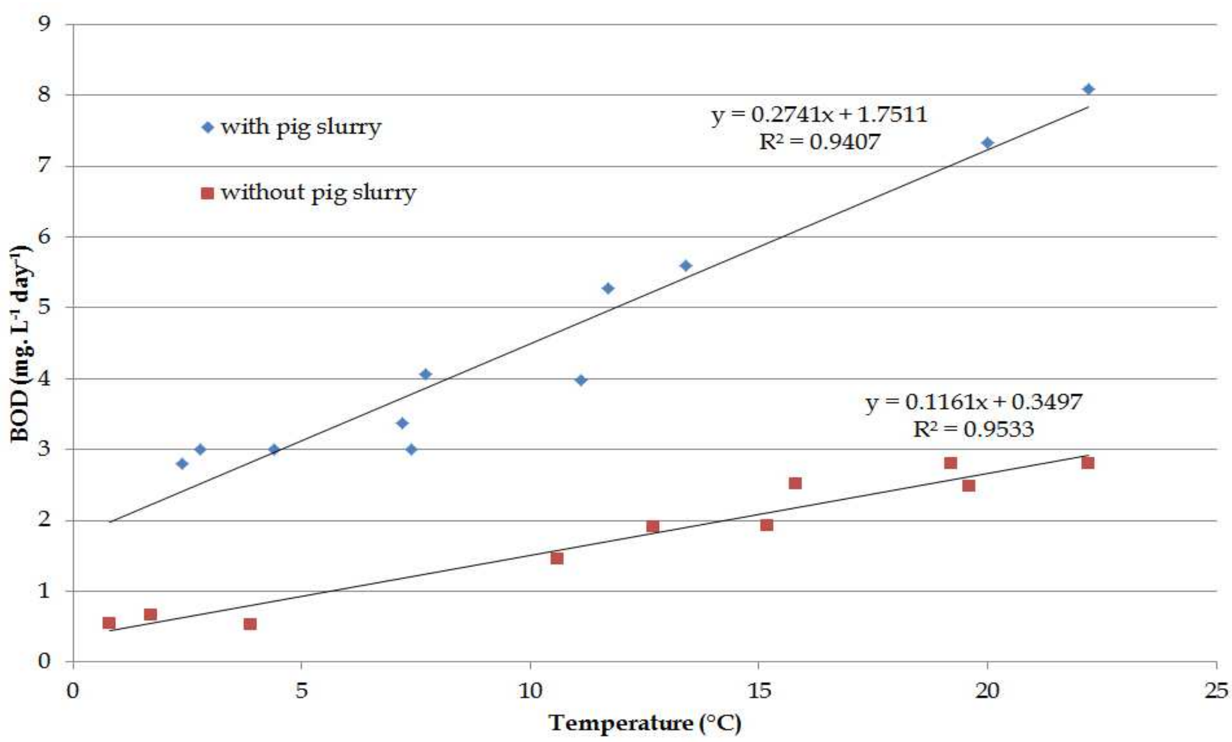

Fig. 8. Regression of temperature with biological oxygen demand (BOD). Pond water without pig slurry was used from pond a year before application and pond water with pig slurry was used during application of 16 kg . m^{-2} of pig slurry (February-May)

Sharma and Das, (1988) also reported that in a fish-pig pond, even higher organic loading by pig slurry did not deteriorate the oxygen content of water. This may be attributed to the higher plankton abundance in manure-loaded ponds, leading to higher dissolved oxygen level by photosynthetic activity especially during day. The values of dissolved oxygen varied during day and night in large interval and after application of pig slurry in during higher development of phytoplankton biomass can be exceed to 250 % saturation within day

(Behrends et al. 1980; Kopp et al., 2008). Figure 9 shows fluctuations in oxygen content during the application of pig slurry at low and high values. In both cases oxygen varied in wide range but has not fall below 50% of saturation, which is limit value ensure survival of carp fish. A wide range of values of oxygen during the application of pig slurry is determined by the intensity of photosynthesis, which is mainly influenced by the amount of available nutrients, water temperature and feed pressure of the zooplankton.

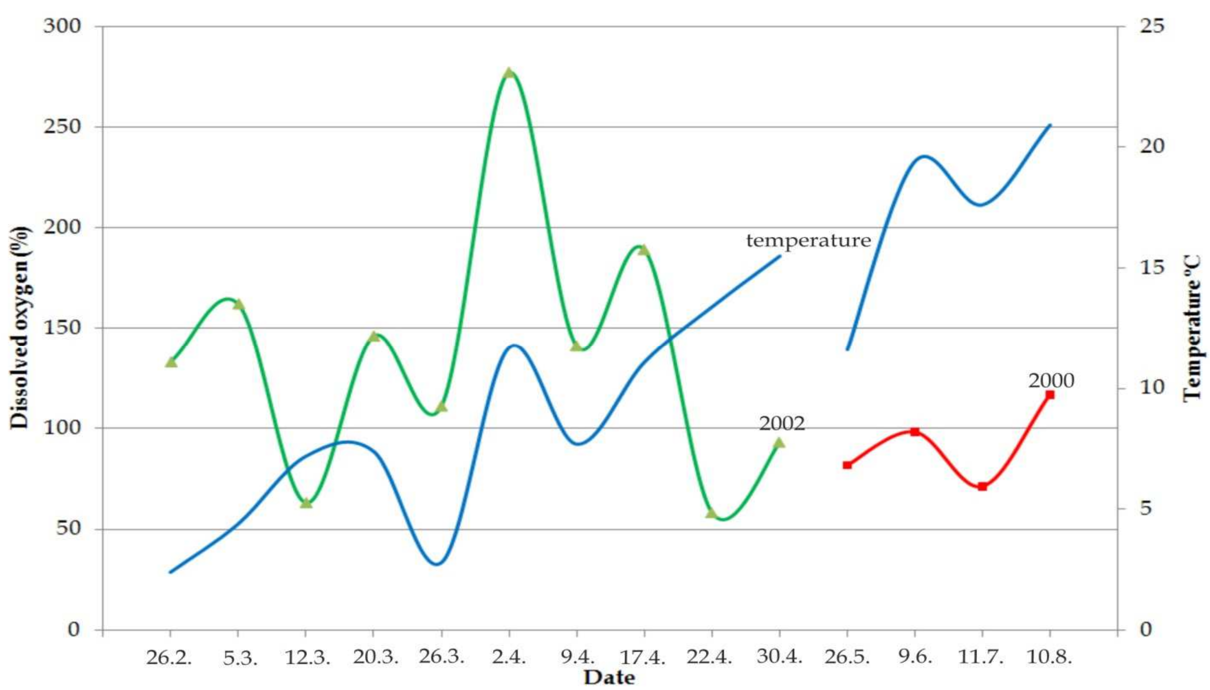

Fig. 9. Variation values of dissolved oxygen during application of pig slurry into the ponds. Level of total doses 16 kg . m^{-2} (2002) and 0.10 kg . m^{-2} (2000) (application began at 9.5. in the year 2000 and 5.3. in the year 2002 respectively)

7. pH

The pH value of water depends on the alkalinity and hardness of the water. Algal photosynthesis causes an increase in pH due to removal of H^+ ions. Algal assimilation of nitrate and its subsequent reduction within the algal cell to ammonium also increases the pH. On the second hand pH decreases with organic fertilization because bacterially generated carbon dioxide from manure decomposition. It was clear that the fertilization regimes were able to maintain adequate buffering capacity so that the pH fluctuations were within the desired limits for fish culture.

Properly chosen dosage and interval of slurry application should keep pH in optimum range for fish farming. To avoid pH increasing (over 8.5) due to intensive photosynthesis of phytoplankton what can happen especially in pond with a low alkalinity it is recommended to add calcium. Dose of calcium fertilizer is set up along of water alkalinity and depends on amount and timing of slurry application. In intensively fertilized ponds is pH usually under 9.0 (Kopp et al. 2008). Figure 10 shows pH fluctuations during the high dose application of pig slurry into intensively managed pond for two years. Significant changes in pH depending on phytoplankton development were apparent in 2001. First two years after slurry application is decreasing pH due to reduced nutrients supply and lower development of primary producers.

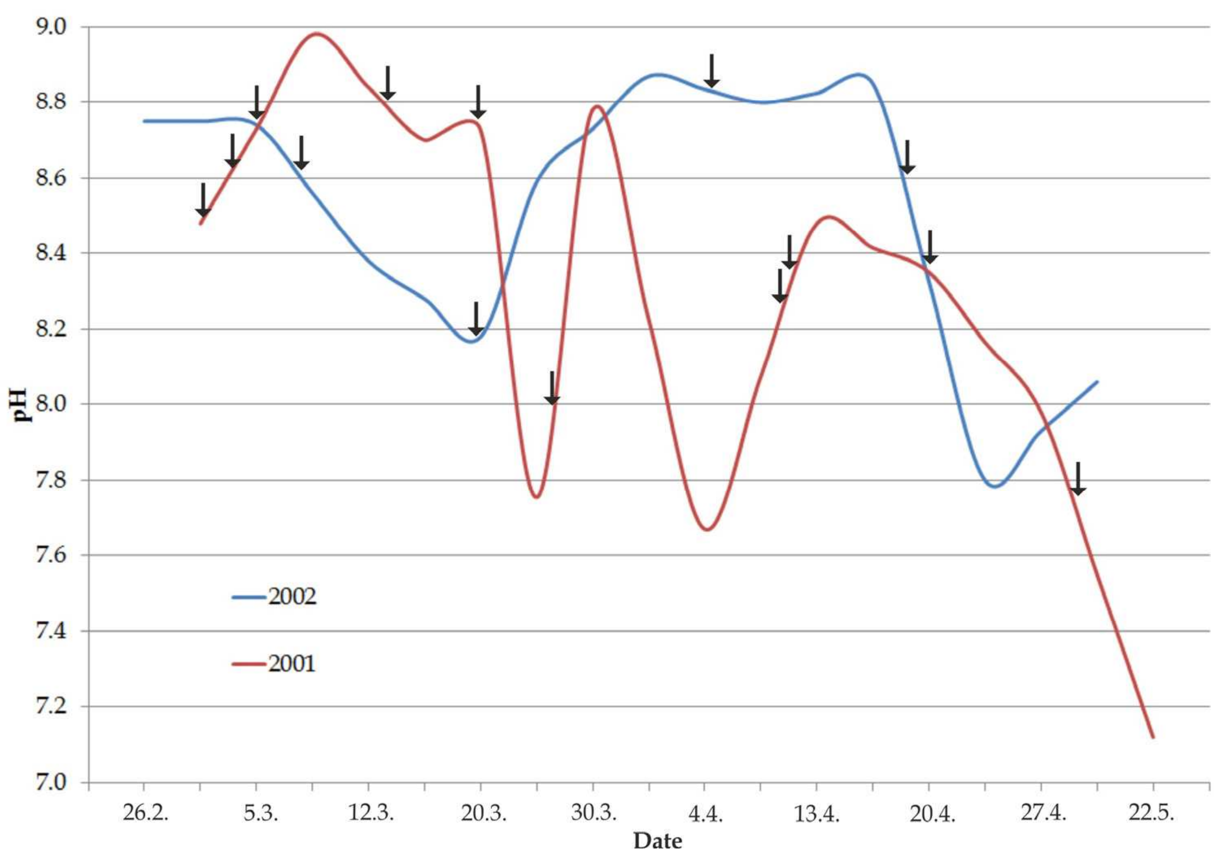

Fig. 10. Variation values of pH during application of pig slurry into the pond. Level of total doses 16 kg . m^{-2} (2001, 2002). (Arrows indicate term of pig slurry application)

8. Transparency

Application of fertilizer at regular intervals affects the transparency of the water. The transparency was significantly worsened within several weeks in the ponds after pig slurry application. Organic particles from manure had a significant influence in water turbidity. Minimum transparency was measured in ponds with abnormal phytoplankton biomass and higher fish stock of cyprinids, which reducing transparency by feeding by pressure on the bottom. High abundance of autotrophs may cause higher development of zooplankton and better transparency. During applications of pig slurry was transparency usually in interval 20-40 cm (Kumar et al. 2004; Kopp et al. 2008). Figure 11 shows different transparency during the high dose application in 2001 and 2002 compare to water transparency in 2003 without pig slurry application. Higher transparency in 2003 was due to lower level of nutrients and lower phytoplankton development in cooler period of the year compare to years with pig slurry application.

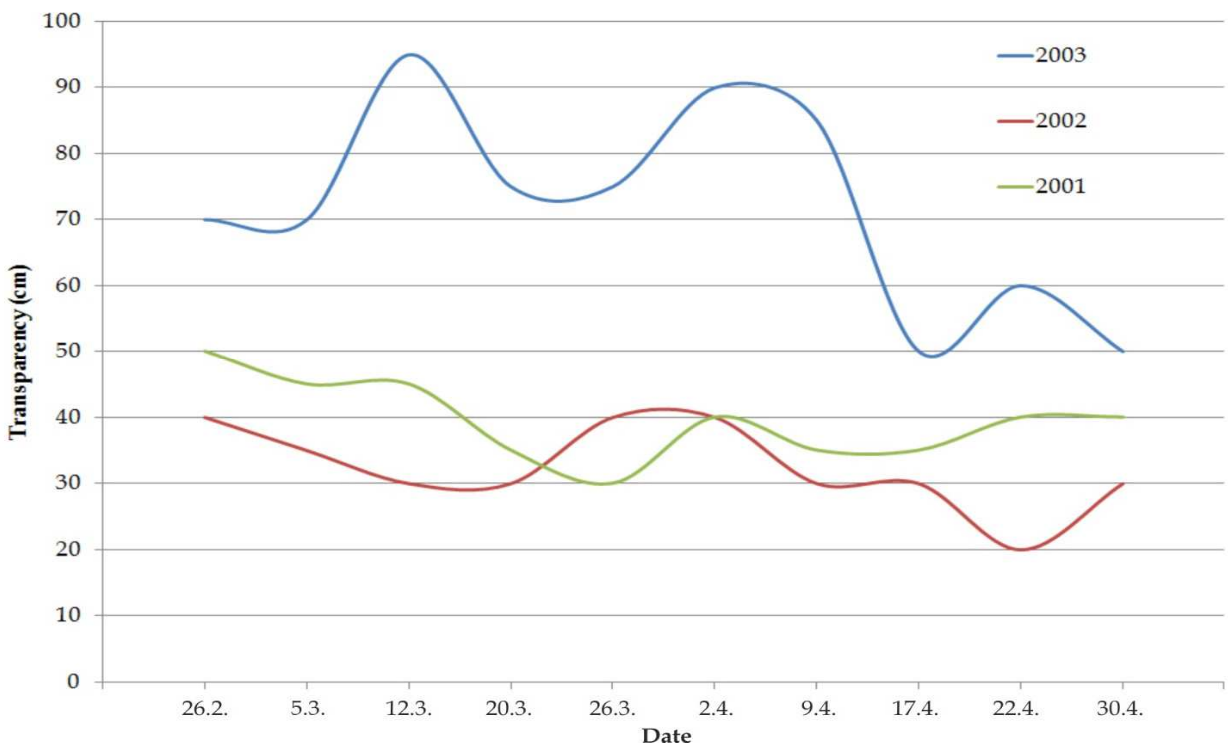

Fig. 11. Variation values of transparency during application of pig slurry into the pond. Level of total doses 16 kg . m^{-2} (2001, 2002) and without application of pig slurry (2003). (Application began at 28.2. in the year 2001 and 5.3. in the year 2002 respectively)

9. Alkalinity

The alkalinity of the water is associated with the level of carbonates and bicarbonates content. The bicarbonate and carbon dioxide in the water has a buffering effect, preventing sudden changes in pH. Low alkalinity (under 1 mmol . L^{-1}) leads to poor buffering capacity and generally, a high fluctuation of pH. A high buffering capacity prevents fluctuation in the acid-base equilibrium caused by strong photosynthetic activity. Alkalinity increases with pig slurry application because bacterially generated carbon dioxide from manure decomposition dissolves calcium carbonate present in the pond sediments and slurry (Kumar et al. 2005). The gradual reduction in alkalinity occurred during the prime period of primary production. According to Boston et al. (1989), a decrease in pond water alkalinity can occur when algae remove bicarbonates. This may occur during periods of high photosynthetic activity which is promoted by application of pig slurry. Figure 12 shows fluctuations in alkalinity during the application of pig slurry into the fishpond. Alkalinity rises at the beginning of application (in accordance with literature) and after that change due to phytoplankton biomass development. Significant decrease of alkalinity during the pig slurry application in 2002 was caused by abnormal plankton development, high intensity of photosynthesis and depletion of carbonates. The alkalinity was quite stable or fluctuates during the year in small interval only in the fishponds that was not fertilizer.

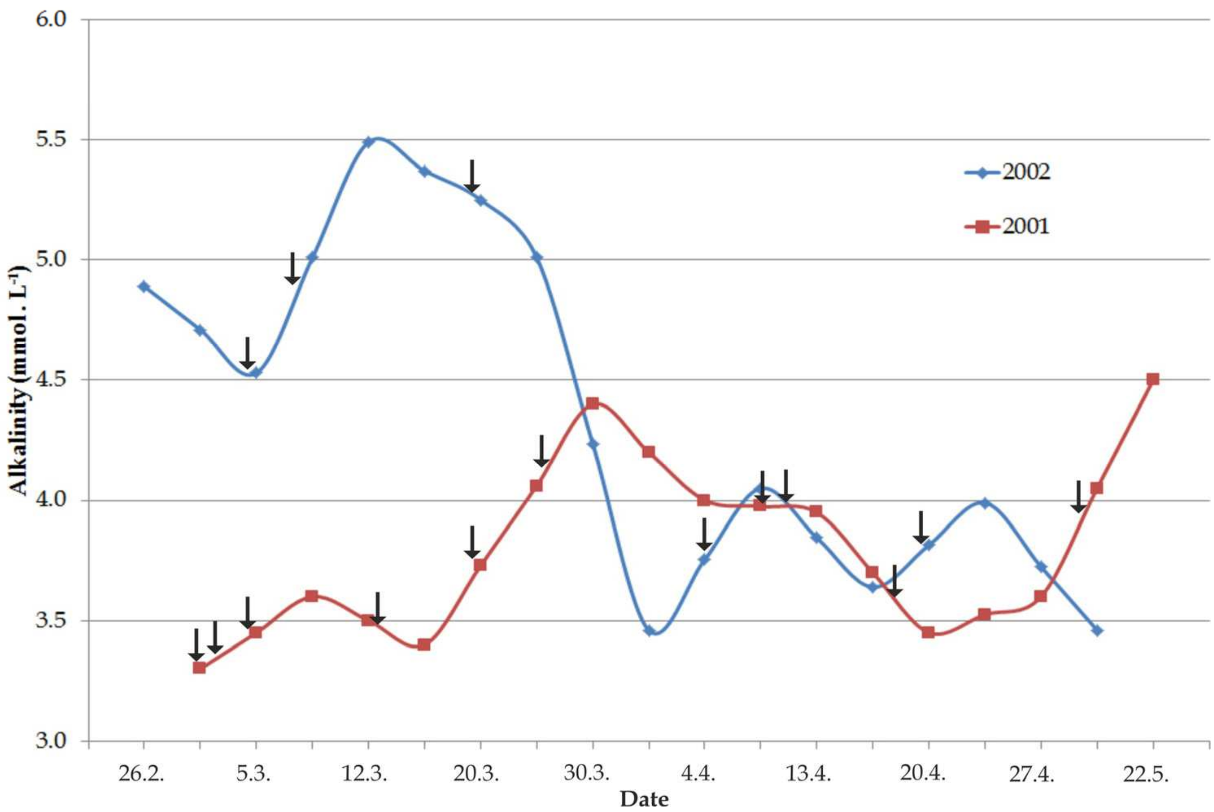

Fig. 12. Variation values of alkalinity during application of pig slurry into the ponds. Level of total doses 16 kg . m^{-2} (2001, 2002). (Arrows indicate term of application pig slurry)

10. Nutrients

The nutrient content of animal manure may vary with time an d the quantity of nutrient released from the manures over time is a key factor in determining the fertilization regime. According to Muck and Steenhuis (1982), manure nutrient concentrations, and the percentage of P, N and C which become available for algal uptake, depend primarily on the animal´s diet, whether the manure is liquid or solid, and the age and storage conditions of the manure. The primary productivity pattern in the pond indicated a gradual built-up phase, a peak phase followed by a decline phase, this can be related to the nutrient release pattern. In pig slurry application, the primary productivity attained its peak 5-7 days after the application of slurry (Kumar et al. 2004).

Culver (1991) and Culver et al. (1993) introduced a fertilization regimen which attempts to optimize the algal composition by maintaining nitrogen and phosphorus at a specific ratio in ponds. They suggested that green algae could be maintained whereas cyanobacterial blooms could be suppressed in ponds by manipulating the N:P ratio (20:1) with fertilizer. Oin et al. (1995) showed that it is difficult to reach the N:P ratio recommended by Culver et al. (1993) by using only organic fertilizer, because most organic fertilizers have a low N and P content and inappropriately low N:P ratios.

Sediment is usually considered the major sink of orthophosphates in fishponds. The sediments absorb soluble forms of P from pond water until fully saturated. The rate of absorption decreases with an increase in partial saturation of sediments (Boyd and Musig, 1981). The P probably accumulates in the newly created sludge layer. Thus, the retained P does not appear to seep into the underground water, but remains in the pond. The P-containing sediment is the basis of the fertility of the pond. The higher P- input into the pond, the more P was retained (Knosche et al. 2000). Pig slurry has a low P content relatively, and application of pig slurry to pond has not negatively impact on higher value of P in outlet water (Kopp et al., 2008; Blažková et al., 1987). Balances of total P and N during the application of pig slurry into the ponds are demonstrated in the Figure 13 and 14.

Nitrogen is one of the most important agents of eutrophication, but it is not the most decisive factor in the eutrophication process of surface waters. Its balance is also influenced by the fixation of N from the air caused by cyanobacteria and by bacterial denitrification. The N balances in carp pond shows the similar picture as the P-retention, i.e. a clear increase in retention with N load (Olah et al. 1994). On the second hand Pechar (2000) reported that the rise in P and N in carp ponds during the 1990s is a result of the higher loading of organic fertilizers, particularly pig and cattle manure. Higher doses of pig slurry increase amount of nitrogen in outlet water from manure pond, especially ammonium for define time (Kopp et al. 2008).

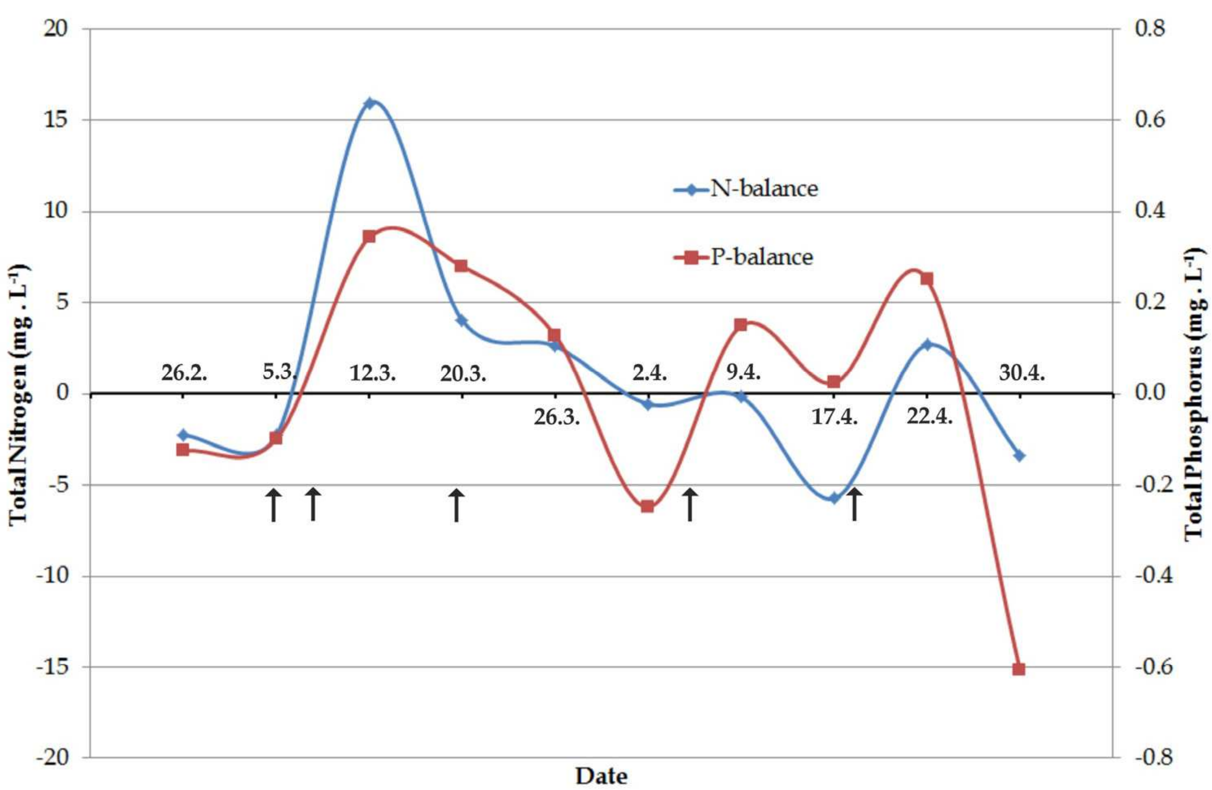

Fig. 13. Balance of total P and N (output by outflow minus input by inflow) during the application of pig slurry (total doses 16 kg . m^{-2}) into the pond (February-April), (Arrows indicate term of application pig slurry)

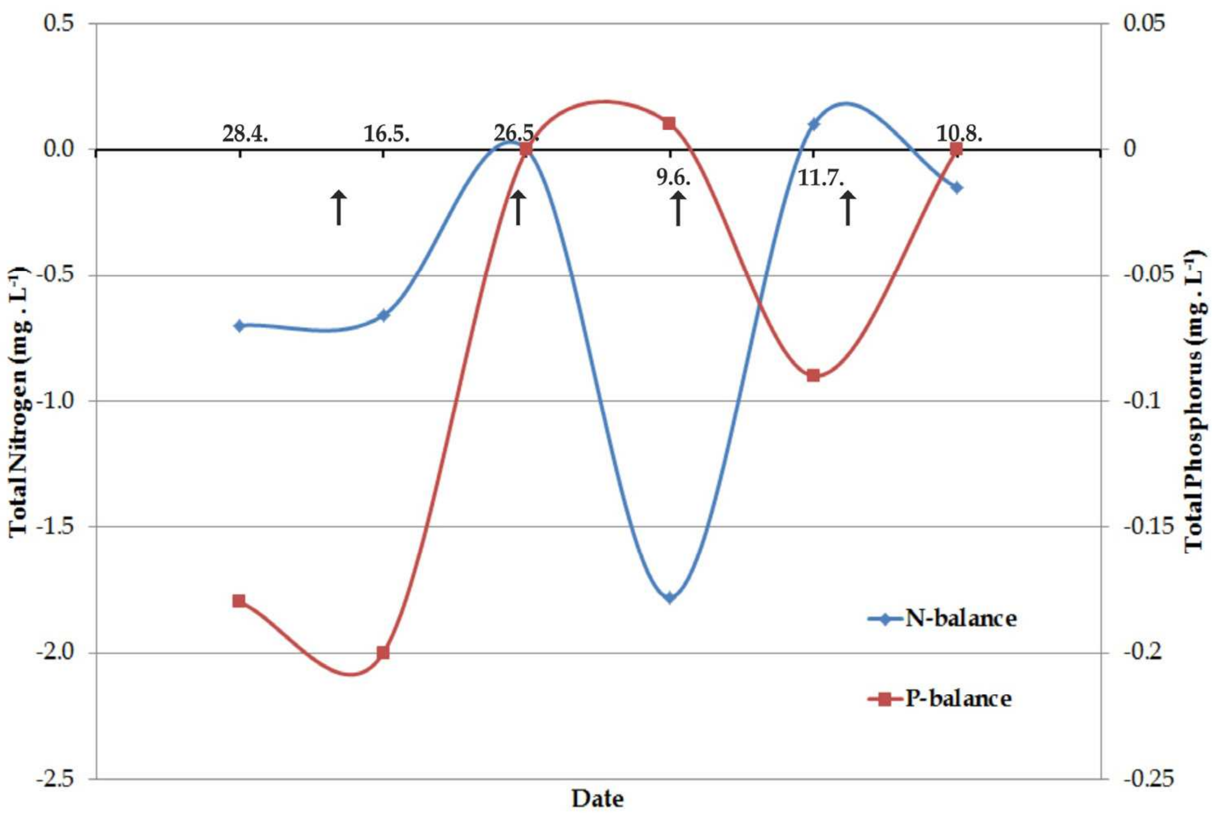

Fig. 14. Balance of total P and N (output by outflow minus input by inflow) during the application of pig slurry (total doses 0.10 kg . m^{-2}) into the pond (May-July), (Arrows indicate term of application pig slurry)

11. Ammonia nitrogen

The critical water quality parameter during application of pig slurry is ammonia nitrogen, a principal excretory product of fish metabolism, which in the un-ionized form is highly toxic to fish. The oxidation of ammonia requires oxygen in the water, for this reason during the initial period of pig slurry application, low levels of nitrate were recorded.

The amount of toxic ammonia depends mainly on pH and water temperature. The maximum allowable (safe) concentration for carp is very low (0.05 mg . L^{-1} NH_3), LC_{50} (lethal concentration) for carp is 1.0 -1.5 mg . L^{-1} NH_3 (Svobodová et al. 1971; Russo and Thurson, 1991). During the application of higher dose of pig slurry has been level of ammonia nitrate increased for a short time which could endanger fish stock by not just acute toxic effects of ammonia but by autointoxication of fish body as well (Kopp et al. 2008). The dosage of pig slurry must follow hydrochemical conditions in pond and application is not possible in high pH or higher water temperature.

Figure 15 shows fluctuations of ammonia nitrogen during the high dose application of pig slurry. The graph clearly demonstrates the significant increase of ammonia in 2002, when were applied higher doses of slurry then a year ago. Despite high level of toxic ammonia in the water there was no fish kills or noticeable reduction of food intake but we can expect some negative impact of sublethal level of ammonia on fish organism. Arrilo et al. (1981)

observed biochemical changes in fish after 48 hour exposure to a low concentration of toxic ammonia (0.02-0.04 mg . L^{-1}). Higher value of toxic ammonia in combination with high pH is show by reduced weight, lower ability to survive and worse feed conversion (Máchová et al. 1983).

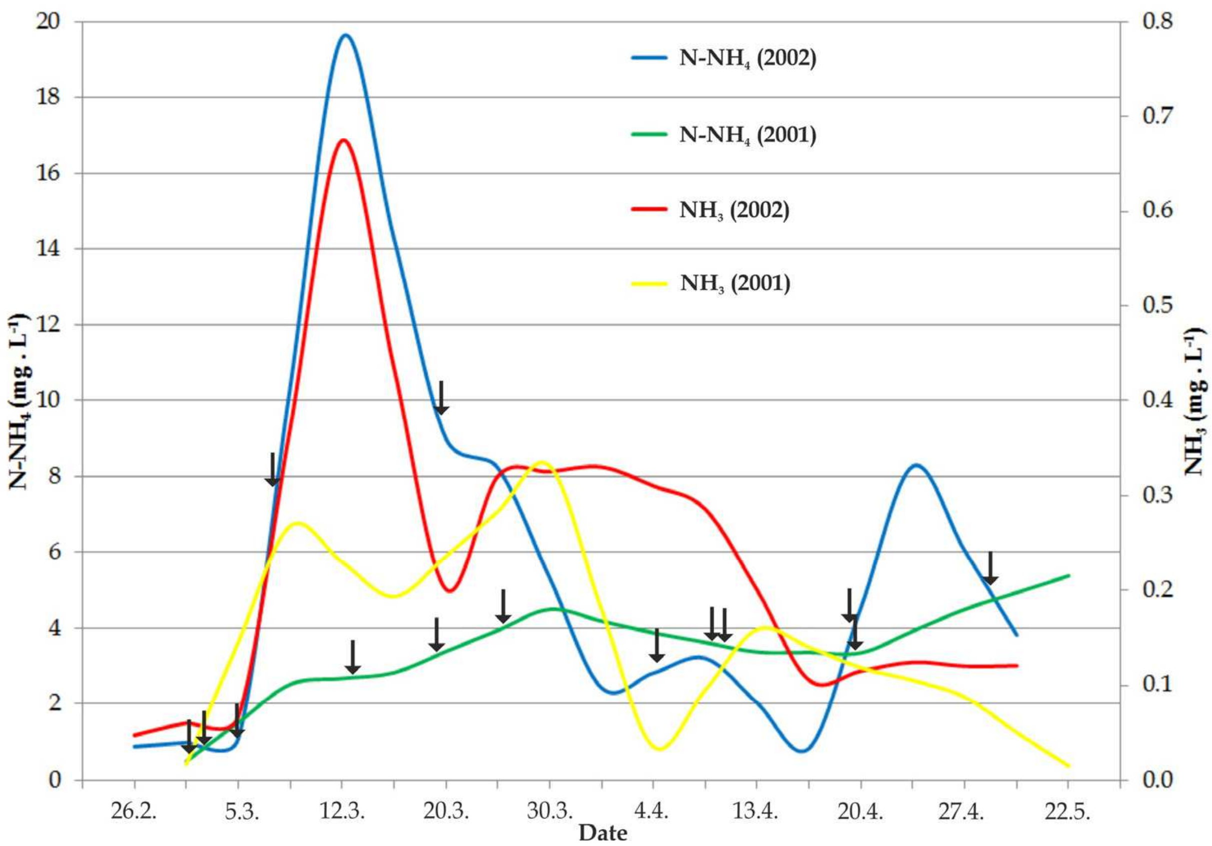

Fig. 15. Variation values of ammonia nitrogen during application of pig slurry into the ponds. Level of total doses 16 kg . m^{-2} (2001, 2002). (Arrows indicate term of application pig slurry)

12. Nitrate and nitrite

The amount of nitrates which gets into the aquatic environment during the slurry application is relatively small compare to ammonia nitrate. Primary producers are using nitrates as sources of nitrogen therefore is negative balance between nitrates intake (water supply, organic fertilizer) and drain from the fishpond. High concentration of nitrates has not negative effect on fish stock but significantly contributes on water eutrophication. In Figure 16 is well show an increase of nitrogen after the start of slurry application and decrease after fertilization. Level of nitrate nitrogen in eutrophic pond often decreases under measurable value due to high assimilation of phytoplankton during the vegetation season (Kestemont, 1995).

Nitrite is an intermediate stage in the oxidation of ammonium to nitrate. Elevated nitrite concentration in water is a potential threat to freshwater fish since nitrite is actively taken up via the gills in competition with chloride and causing elevation of methaemoglobin levels (Russo and Thurson, 1991). Application of pig slurry to the water is bringing a lot of nitrate nitrogen. As show Figure 16, even during the high dose of slurry the value of nitrates is not dangerous for fish organism. Due to their chemical and biochemical instability nitrites in toxic environment are quickly transformed into nitrates and use by phytoplankton. Even in case of short term high value of nitrites due to single application of pig slurry fish are protected against the toxic effect of chloride ions which are a normal part of surface water (Jensen, 2003).

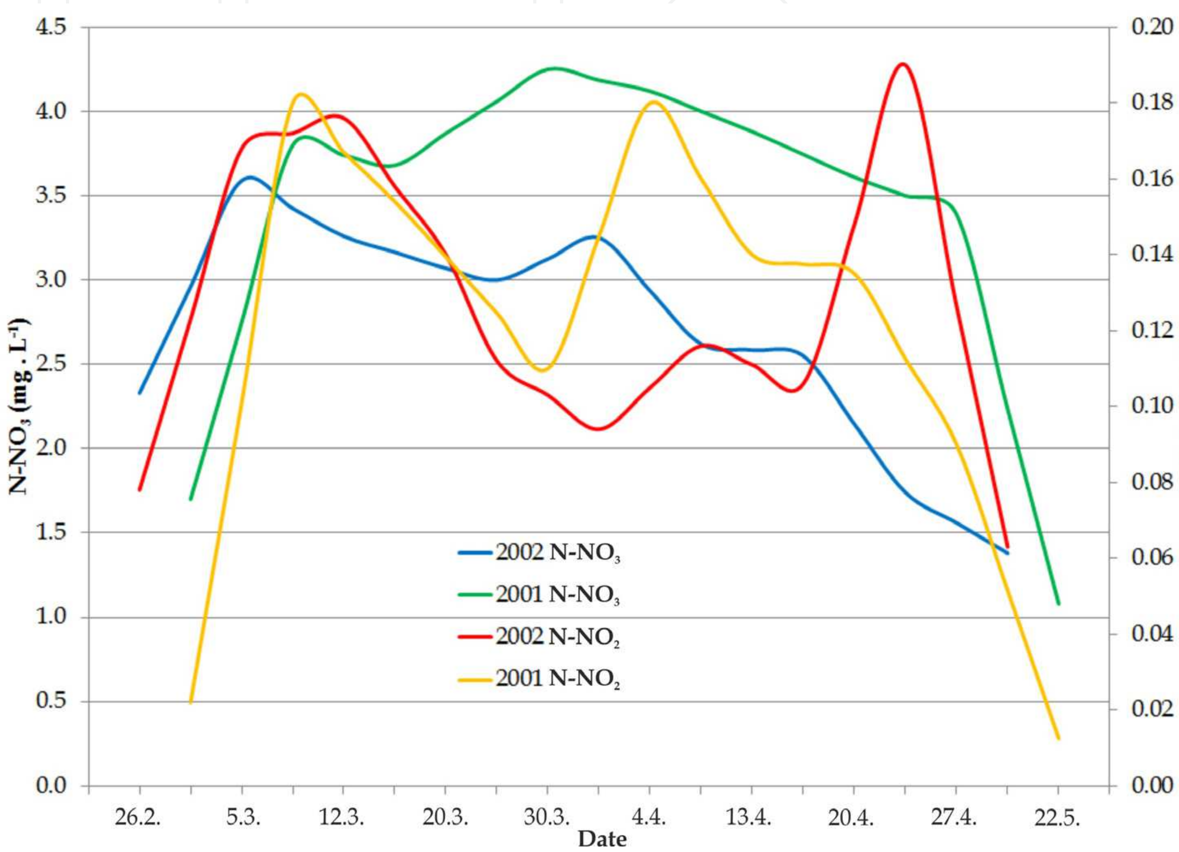

Fig. 16. Variation values of nitrate and nitrite during application of pig slurry into the pond. Level of total doses 16 kg . m-2 (2001, 2002). (beginning application at 28.2. in the year 2001 and 5.3. in the year 2002 respectively)

13. Conclusion

Dhawan and Kaur, (2002) presented that pig dung, as pond manure which even at higher dose did not adversely affect water quality. Likewise Kajak and Rybak, (1980) advised, than even the heaviest load of nutrients from pig slurry which was added to water did not destroyed the functioning of the ecosystem until an “ecological catastrophe” resulted. A significantly higher plankton production was also recorded in this treatment. However, indiscriminate use of pig dung may deteriorate the water quality and hence decrease plankton production (Boyd and Doyle 1984). Preliminary determination of doses and composition of organic fertilizer to be introduced seems advisable. Another solution will might be able to allow enough time to recover the desired water quality after the introduction of organic fertilizer. The enormous quantities of organic fertilizers and the high fish stock densities in ponds resulted the presence of very small-sized group of zooplankton.

The phytoplankton blooms elevated pH levels and decreased the N:P ratio. Cyanobacteria, *Planktothrix agardhii* and *Limnothrix redekei*, typical of hypertrophic waters have become common (Pechar, 1995).

Pig slurry is used especially to supplement carbon into water. Due to change of environmental condition by human, eutrophication of fish ponds is increasing. Uncontrolled and unbalanced input of nutrients causes a disparity of basic biogenic elements N, P, which are in excess to carbon. High assimilation of plants makes carbon a limiting element for another production. This situation is common especially in ponds with intensive fish management (Sukop, 1980). It is necessary to implement the ameliorative intervention in colder period of the year considering higher hazard of variations of decisive hydrochemical parameters at higher water temperature. Unsuitable influence of high single doses of pig slurry on hydrochemical parameters is evident especially by higher values of toxic ammonia (Kopp et al. 2008). Pig slurry application has only short-term influence on water quality. Values describing that high organic pollution are noted immediately after the application. Adequate doses of pig slurry and acceptable form of its distribution to ponds does not cause permanent decline of water quality. Influence on values of physical and chemical parameters in water is not permanent (Sharma and Olah, 1986; Blažková et al., 1987).

From the water management point of view, ponds are not a burden to the environment, but generally improve the water quality downstream of the ponds. A claim for the reduction of production intensity in pond aquaculture cannot be justified from the water quality concerns. Carp ponds generally release better-quality water than these water bodies receive as inflow. Additionally, ponds act as water storage basin and improve the microclimate.

Public attention in recent years is focused on negative impact of agriculture on nature. High eutrophication of the water environment is decreasing biodiversity, causes abnormal water bloom development and fluctuations in physico-chemical parameters. So the application of organic fertiliser could be a problematic issue thought positive impact on fish production. Considering to the pressure of the human society on better environment the application of this kind of matter (i.e. pig slurry) into the water is strictly restricted in many countries.

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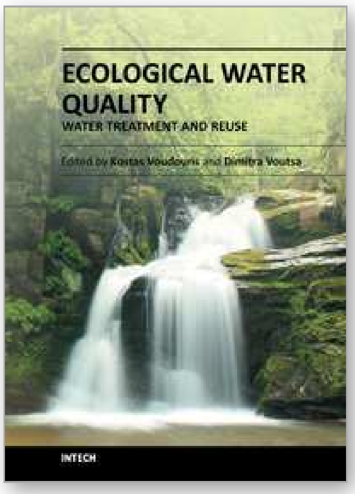

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