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ORIGINAL RESEARCH ARTICLE

Influence of dissolved organic nitrogen on surface waters☆

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Summary The aim of this study was to determine the susceptibility of dissolved organic nitrogen (DON) contained in biologically treated wastewater disposed from municipal wastewater treatment plants (WWTPs) to biodegradability and bioavailability in a water environment. Additionally an evaluation was performed of the participation of this organic nitrogen fraction, including bioavailable DON (bDON), in the nitrogen balance for the Baltic Sea.

Based on the samples of secondary effluent taken from two large municipal WWTPs located in Northern Poland DON bioavailability and biodegradability tests were carried out. It was concluded that DON concentration in the tested samples was on average from 1.5 to 2.0 g N m^{-3}. This fraction constituted as much as 50% of organic nitrogen and 15—18% of total nitrogen contained in treated wastewater.

The participation of biodegradable DON (brDON) in activated sludge tests was on average 24—35%. In the bioavailability tests *Selenastrum capricornutum* were able to use from 19 to 26% of DON, however taking into account the results of the control test, these values are reduced to 3—4%. On the other hand, taking into account the combined effect of bacteria and algae it was possible to reduce the DON concentration by nearly 40%.

The estimated annual bDON load introduced to Baltic Sea waters from Poland through disposal of treated biological wastewater in 2010 reached up to 1.7 thousand tons of N $year^{-1}$.

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1. Introduction

European Union legal regulations in terms of disposal of treated municipal wastewater are specified particularly in the Council of European Communities directive 91/271/EEC dated May 21st, 1991. It imposes the obligation on member states to ensure at least a good condition of surface waters by the year 2015. In Poland the priority task in protecting surface waters, flowing waters and the Baltic Sea waters against pollution caused by municipal wastewater is to ensure complete biological treatment of wastewater and increased removal of biogenic compounds in urban centers above 15,000 PE. This should at minimum provide 75% reduction of the total nitrogen (TN) and phosphorus load in municipal wastewater from all over the country. The achievement of the intended nitrogen load reduction effect is associated with reducing the concentration of inorganic forms of nitrogen contained in secondary effluents and primarily involves improving the effectiveness of the nitrification and denitrification processes carried out in bioreactors of municipal wastewater treatment plants (WWTPs). However, in biologically treated wastewater, organic nitrogen (ON) may constitute a significant participation of the TN. This directly influences the functioning of large municipal WWTPs in Poland (above 100,000 PE), for which the admissible TN concentration in sewage disposed to the receiving bodies is 10 g N m^{-3}. The results of studies conducted so far domestically and abroad show that the participation of dissolved organic nitrogen (DON) in treated wastewater is less than 2% up to as much as 85% of the total nitrogen (e.g. Pagilla et al., 2008). In such a case, the origin, fate and degree of bioavailability of the dissolved fraction of ON in treated wastewater constitutes a significant issue in the perspective of protecting waters against eutrophication. If the degree of this fractions availability in wastewater receiving bodies is high, the goal should be to develop wastewater treatment technologies taking into account removal of DON. If, however, the fraction is not bioavailable also outside of wastewater treatment plants, this fact should be reflected in regulations on the quality of treated wastewater. In the treated wastewater receiving bodies as a result of ammonification the increase of the ammonia concentration may occur. The limiting factor of this increase is the ammonification process rate. Ryzhakov et al. (2010) have identified this value at 0.004–0.035 mg N dm^{-3} d^{-1} based on the studies of the four lakes. In a typical municipal wastewater treatment plants ammonification rate was higher, and amounted above 50 mg N dm^{-3} d^{-1} (Katipoglu-Yazan et al., 2012). However, the studies concerning the impact of wastewater discharge (containing DON) on the Chesapeake Bay Lake did not show a significant increase of ammonia concentration, which was completely consumed within 2 days (Filippino et al., 2011).

Organic nitrogen is disposed into ground waters from natural sources (atmospheric precipitation, swamp areas, infiltration) and as a result of the human activity (agriculture, intensive animal farming and treated wastewater). It accesses the water as a result of a single point disposal (e.g. from treatment plants), surface flows and atmospheric precipitation (Seitzinger and Sanders, 1997, 1999). DON may have a significant participation in the total amount of nitrogen available in most water systems, also including oligotrophic waters (lacking in biogenic compounds), in which original production is limited by the availability of nitrogen (Bronk et al., 2006). In such cases ON may constitute a significant source of this element for the growth of microorganisms. It should be, however, taken into account that DON is created by compounds of varying molecular weight, lability and bioavailability. Literature features publications regarding the possibility of using DON by the water ecosystem, including bacterioplankton, cyanobacteria and phytoplankton (Berman, 1997; Berman and Chava, 1999; Bronk et al., 2006). Results of experimental studies show that in river and lake waters DON constitutes an average of 40–50% of TN, however its participation may exceed 85% (Kroeger et al., 2006). An inverse relation between DON concentration and the concentration of dissolved inorganic nitrogen was observed, which indicates that DON may be an alternative source of nitrogen for microorganisms. According to Seitzinger and Sanders (1997) the participation of DON varies between 20 and 90% of the TN load in estuaries.

The participation of DON biologically utilizable for microorganisms primarily depends on its characteristics. It has been concluded that compounds of a low molecular weight (LMW) are more easily available in sea waters, as well as fresh-waters compared to the high molecular weight (HMW) compounds, whereas a significant part of DON consists of compounds not susceptible to biodegradation (Stepanauskas and Leonardson, 1999). The sources of DON origin and environmental conditions may also be of particular significance. Based on the results of tests incorporating bacteria and algae it was concluded that the degree of DON use also depends on the season. During spring floods Seitzinger et al. (2002) have observed an increase in DON bioavailability despite its concentration being maintained at a stable level. The authors point out that DON released from the soil is less utilizable for microorganisms than DON originating from other sources, e.g. discharged from a treatment plant. This may be due to the fact that DON from agriculture and forest areas contains aromatic compounds, while municipal wastewater DON contains primarily aliphatic compounds. Aliphatic compounds are more easily utilizable for microorganisms compared to aromatic compounds, which may indicate the existence of a correlation with the availability of nitrogen. The degree of DON usage was between 0 and 73%, whereby the higher values were observed for ON originating from municipal, rather than natural sources (like forest area runoff). Also, in the opinion of Wiegner and Seitzinger (2004) DON from municipal sources influences higher bacteria growth. The degree of DON usage by microorganisms in a water environment (rivers, streams, swamp areas and seas) is variable and fluctuates depending on the author from 0 to 80% (Bronk et al., 2006; Stepanauskas and Leonardson, 1999; Wiegner and Seitzinger, 2004).

Berman (1997) presents data indicating that LMW compounds included in DON may be directly or indirectly digested by microorganisms. In the Kinneret lake (Israel) studied by him the concentration of DON decreased from 0.371 to 0.125 g N m^{-3}, and the concentration of dissolved inorganic nitrogen decreased from 0.065 to 0.013 g N m^{-3}, as a result of the development of *Aphanizomenon ovalisporum* Cyanobacteria. These results indicate, that compounds which comprise DON are an important direct and indirect source of nitrogen for microplankton. This conclusion has been