Stoichiometry of carbon forms in a small humic lake

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Abstract

The medium concentration of total organic carbon (TOC) in a small (A=24 ha), shallow (z_{max}=7 m) and midforest lake Pereszpa in the east of Poland was 15 mgC·dm^{-3}, whereas the concentration of DOC constitutes 90% TOC. Organic forms of carbon are in balance with inorganic forms, although a wild range of quotient TOC to DIC informs about periodic variability catchment's lake feed with organic compounds or about internal carbon changes. These changes are connected with periodically decreasing POC:chla ratio or increasing quotient DIC:DOC:chla (respectively 240-3155:269-2062:1) in presence of intensive microbiological respiration. In this lake it lead to alternating domination of the plankton organisms characteristic for hetero-, mixo- and autotrophic lakes.

Key words: humic lake, dissolved organic carbon, particulate organic carbon, total organic carbon, dissolved inorganic carbon, mixotrophic lake, biogeochemistry.

Introduction

The application of stoichiometric findings in water ecology usually leads to estimation of balance between the concentration (molar or mass) of carbon, nitrogen and phosphorus (C:N:P) [1, 2, 3, 4]. Findings on rough appraisal allowed to define which of analysed elements are limiting factors for development of primary producers in oligo- and mesotrophic lakes [2, 4, 5, 6, 7]. In eu- and hipertrophic lakes and lakes with colours water the development of photolithoautothrophic organisms is usually inhibited through by physical factors eg. deficiency of active photosynthetic light [8, 9, 10, 11].

Some of the factors which decide about trends in lake evolutions in time is quality and quantity of carbon in water [9,, 10, 12, 14, 15, 16, 17]. Carbon structure has been well known in Polish young-glacial dystrophic and harmonic lakes [14, 18, 19, 20]. There is no information about biogeochemical functioning of lakes surrounded by peat bogs, which are located in periglacial Baltic glaciation's area.

The aim of this investigation was an estimation of diversification carbon forms in midforest lake surrounded by peat bogs. If such phenomena one has to assert, whether it could inform about functional aspects of the lake.

Area and methods

Between 1996 and 2002, 8 positions of midforest lake Pereszpa (on the east of Poland, λ=23°37'E, φ=51°35'N) were investigated. This outflow lake is longitudinally located and consists of 2 basins. Podsolic and marshy or peaty soils dominate in the catchment's soils. The organic soils constitute about 15 % of basin surface and develop in low-located accumulation plains, mainly on the lake shore zone [21]. Dry, fresh and marshy coniferous forests dominate in the catchment area.

The lake has been characterised as humoeutrophic for the sake of resources of TP, abundant of organic matter and neutral (or alkaline) pH of water [21]. In the summer, on the level of 4,5 m anoxic water appears and concentration of chla in a surface water is similar to dystrophic and moderate eutrophic lakes [14, 21].

Taking of water samples and hydrochemical analyses were determined according to the limnological methods of site surveys and laboratory investigation [22, 23]. Hydrochemical dates were calculated from 42 site surveys carried out in spring, summer and autumn. Determine of organic carbon was performed in non-filtered water by titration or spectrophotometric method with potassium dichromate. Dissolved organic carbon (DOC) was performed after filtration with filter's diameter of pore 0,45 µm (Sartorius or Nucleopore).

Determine of DOC was performed by titration or spectrophotometric method. From the difference between TOC and DOC concentration of carbon in POC (organic carbon in seston) was calculated. Forms of inorganic carbon (DIC) were performed by titration method with EDTA. During the study the pH of lake water was 4,5-8,3 , therefore the obtained test results are accepted as concentration of DIC (TIC). The concentration of chlorophyll a (chla) was performed by spectrophotometric method after extraction in boiling 90% ethanol [24]. Obtained results of concentration of carbon forms were calculated on the basis of the carbon concentration [$mgC \cdot dm^{-3}$]. In case of chla was applied conversion factor 0,7399.

Results

The concentration of dissolved organic carbon forms constitutes usually 90% of TOC and was statistically correlated (r=0,93, p<0,001, n=336) with concentration of organic carbon, which amounts to 15 mgC·dm^{-3} (Tab. 1). Concentration of chla (mean 17,1 µgC·dm^{-3}) constitutes 1,1% of POC concentration (Tab. 1). Concentration of POC and DOC was inverse proportion correlated (r=-0,68, p<0,001), like the concentration of TOC and DIC (Fig. 1). Relatively high variability factors and max and min quotient value of organic and inorganic forms of carbon show substantial dynamics throughout the year and between seasons (Tab. 1).

Wild range of TOC:TIC ratio (0,52-2,53, Fig. 1) shows alternating domination of organic and inorganic forms of carbon in water. Then a range of quotient POC:chla (17-364:1) simultaneously with median equal 78 informs, that the balance of the TOC apart from photoautotrophic bioseston plays an important role resuspended organic matter and heterotrophic organisms (Fig. 2).

Seasonal small bioavailability of DOC inhibits bacterioplankton development (Fig. 2). It shows a wild range (269-2062:1) of equal DOC:chla level on median value. Whereas the fluctuation of DIC:DOC:chla (240-3155:269-2062:1 respectively, median 890:874:1) informs about seasonal increase respiration of plankton.

Discussion

Feeding of DOC from organic and podsolic soils guarantees the stability of inflow dissolved carbon forms into lake: frequently occasional inflow DOC from mineral soils and long-lasting import DOC from alder carrs and peat bogs [21]. Thanks to this “double feeding” of DOC seasonal fluctuations of this parameter are small, unlike many other clear water lakes [14, 19].

Significantly a part of organic matter in Pereszpa lake is allochtonous and reaches the water body at high water level [21]. Under anaerobic conditions of the decay composition of DOC is limited. This process favours an accumulation of allochtonous matter [9, 25]. The lower values of DOC:DON quotient on the surface of the north part provides it, compared to bottom stratum [21]. The quality of organic matter in the south polimictic part of the lake shows significantly the participation of phytoplankton and macrophytes in forming DOC store [21].

Therefore about of this lake decides periodical hydrological increase of speed inside-like respiration of allochtonic organic matter about the working of this lake [3, 21]. Important basins import of DOC starts so-called “microbiological loop” [26, 27, 28]. That is why the DOC concentration in this lake, is correlated direct proportionally to chla signs and lake level [21]. Moreover humic index is inversed proportionally to N:P quotient [21].

Trophogenic zone in lake Pereszpa spreads in the water to a depth of 1 m enclosed long spreads about 30% of total volume of lake (in a presence of medium water level and small depth of the lake). All this things explain maintaining of substantial anoxic water [21]. To take assumption [29] we can estimate, that 36% of organic carbon is used during the respiration. The speed of respiration calculated on the basis of chla and DOC concentration is 31mg $O_2 \cdot m^{-3} \cdot h^{-1}$ on average and is threefold lower than respiration calculated on the basis of TP concentration [21].

20 to 60 % of lake’s TOC is metabolized by heterotrophic bacteria in aphotic and anoxic water [25]. A product of this metabolism is CO_2 and CH_4, which under aerobic conditions transform into CO_2 which (after dissolved) forms DIC [25]. DIC comes into existence internal respiration decreased pH lake’s water and because of that is destabilizing factor of sestonic complexes of Ca and P [21]. Consequently, it possibly leads to internal eutrophication of phosphorus existing in lake water (but does not leads in basins as lacustrine sediments).

The indicator of TOC:DIC equals 0,95 and informs that organic carbon forms are in balance with inorganic carbon forms, and the lake is characterized by features which are something between harmonic and disharmonic lakes [14].

The Pereszpa lake shows features indirect between typical auto- and alloiotrophic lakes [31], with mixotrophic [9, 10] or humoeutrophic [14] features. It means that the lake has the features of both, anabolic (or autotrophic) and catabolic (or heterotrophic) lake [30].

At the moment lake Pereszpa exists in a dynamic balance resembling *alternative stable states* of macrophytes-phytoplankton present in shallow clear water lakes [9, 31]. On account of water’s colour and adverse conditions of elodeids development, they play a minor role in lake functioning. Determined by basins feeding stoichiometric of carbon forms a base to form alternating domination characteristic to hetero-, mixo-, and autotrophic organisms in lake water [21].

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Tab. 1. Concentration of characteristic forms of carbon in lake Pereszpa (1996-2002, n=336).

parameter	unit	mean	min	max	SD
TOC	[mgC·dm^{-3}]	15,0	11,9	21,7	1,91
POC	[mgC·dm^{-3}]	1,6	0,3	3,5	0,67
DOC	[mgC·dm^{-3}]	13,5	9,9	19,4	1,85
DIC	[mgC·dm^{-3}]	17,2	8,5	27,7	4,02
chla	[µgC·dm^{-3}]	19,3	5,9	42,1	9,56

Fig. 1. Relationship between concentration of TOC and DIC In lake Pereszpa (1996-2002, n=336).

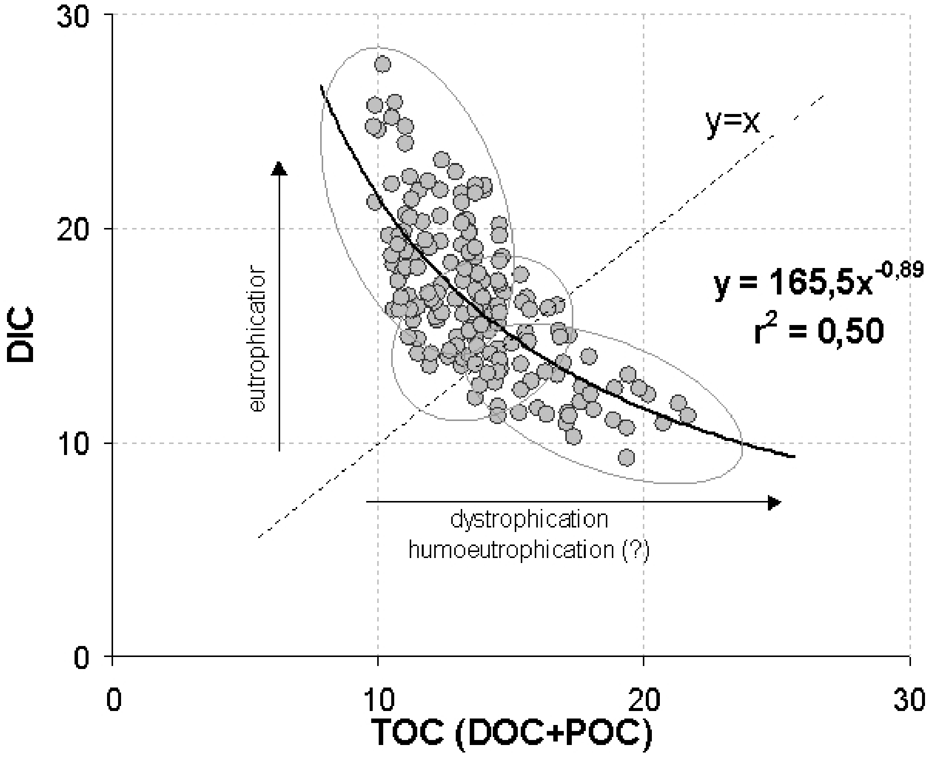
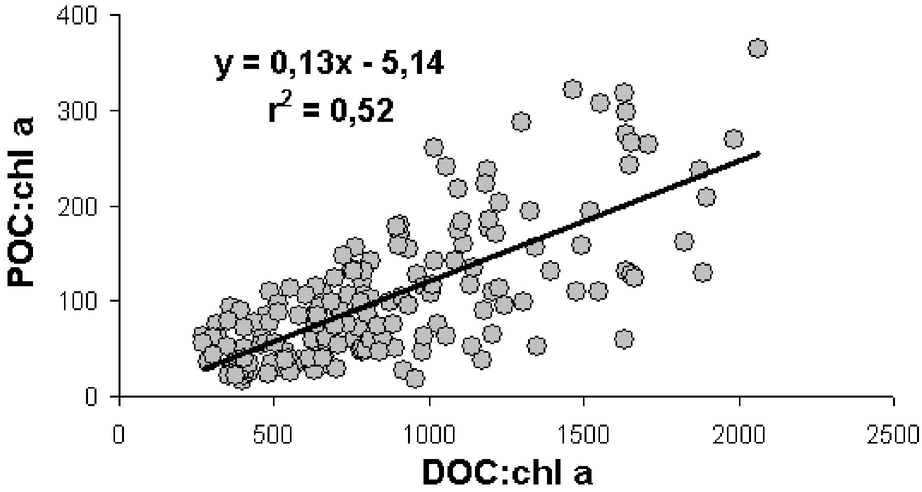

30
20
10
0
DIC
eutrophication
y=x
y = 165,5x-0,89
r2 = 0,50
dystrophication
humoeutrophication (?)
0
10
20
30
TOC (DOC+POC)

Fig. 2. Relationship between mass indexes DOC:chla i POC:chla (a) and DIC:chla and DOC:chla (b) in lake Pereszpa (1996-2002, n=336).

(a)



(b)