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QUALITATIVE AND QUANTITATIVE CHARACTERISTICS OF ORGANIC MATTER IN THE WATER OF A SMALL RESERVOIR

KATARZYNA PARSZUTO, RENATA TANDYRAK, JAROSŁAW GALIK

University of Warmia and Mazury in Olsztyn, Faculty of Environmental Sciences and Fisheries,
Chair of Environmental Protection Engineering
ul. S. Prawocheńskiego 1, 10-957 Olsztyn-Kortowo, Poland
Corresponding author e-mail: kasiapar@uwm.edu.pl

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Abstract: The aim of this study was to determine the qualitative and quantitative characteristics of organic matter in water of a small reservoir Modrzewiowy Pond using a SUVA indicator, particulate organic carbon (POC) and dissolved organic carbon (DOC). The concentrations of total organic carbon (TOC) and DOC were determined using a Shimadzu TOC-5000 analyzer. The POC value was obtained from the difference of TOC and DOC. High average TOC concentration (32.20 mg C·dm^{-3}), resulting mainly from high POC (21.03 mg C·dm^{-3}) in TOC, maximum SUVA parameter (30.87 dm^3·cm^{-1}·(g C)$^{-1}$) and chlorophyll concentrations (75.60 mg·m^{-3}) and pheophytin (94.39 mg·m^{-3}), was observed in the over sediments waters of the pond. The high value of the SUVA indicator in the water of Modrzewiowy Pond, prove high-molecular organic compounds resistant to biodegradation in the DOC pool. The examinations showed a significant influence of the primary and secondary production on the quality and the amount of organic matter in the examined reservoir.

INTRODUCTION

A perfectly functioning small water reservoir with its aquatic and riparian vegetation stabilizes the level of ground waters, reduces the runoff variations, and, first of all, is responsible for the local water retention [25, 28]. Small lakes also constitute a kind of a biogeochemical barrier catching the local flow of biogenes and contaminants to the system of surface waters [22, 23, 40]. In view of their instability and multitude of advantages, mostly natural and ecological ones [18, 20, 24, 27], but also economic and recreational ones, the protection of this type of natural environmental elements is important.

One of the methods of classifying a reservoir to the trophic level is by analyzing dissolved natural organic matter present in the water using spectrophotometric absorption spectra and determining the Specific UV Absorbance index (SUVA) [9, 10].

The amount of organic matter determining a reservoir's trophy can be measured directly by means of the forms of particulate (in suspension – POC) and dissolved (DOC) organic carbon [35], the variability of which depends, among other things, on the productivity of a lake [32, 33].

The aim of this study was to determine the amount of organic matter in the water of a small reservoir, Modrzewiowy Pond, with the use of organic carbon forms – POC and DOC and its quality on the basis of the SUVA index.

MATERIAL AND METHODS

Modrzewiowy Pond is situated in the south-west of the city of Olsztyn, in the area of Kortowo university campus [46]. Its area is small and amounts to 0.8 ha. The maximum depth of this reservoir reached 6 m and was changing depending on the variations of the water level. The pond is an artificial formation. Previously there was a clay-pit there.

According to Solarski [42], the Modrzewiowy Pond catchment was of agricultural nature in the 60s, while in the 90s Gawrońska *et al.* [7] estimated it as waste land. At present its catchment is of urban character. On its western side, the pond abuts on a residential quarter (detached houses), and on the eastern and southern part – on church buildings. The southern shore of the reservoir is surrounded by a high scarp, planted with trees according to Solarski's project in the early 60s [42]. In the central part of Modrzewiowy Pond there is a small wooded islet. This reservoir has been used by anglers for years [46].

Water for analysis was collected from the depth of 1 m and 5 m over the deepest place of the reservoir using Ruttner's apparatus, from 19 May 2006 to 13 December 2007.

Water was filtered through a glass fiber drain – GF/C (pore dimension 1.6 μm, Whatman) and membrane drain (pore dimension 0.45 μm, Sartorius). The concentration of total particulate organic carbon (T-POC = POC > 0.45 μm) and POC released on the GF/C filter (POC > 1.6 μm) were obtained from the difference of organic carbon contained in the non-filtered sample and the sample filtered through an appropriate filter. The amount of the POC fraction of the dimension of 0.45 μm < POC < 1.6 μm was obtained from the difference between the contents of T-POC and POC > 1.6 μm. The concentrations of the dyes: chlorophyll a and pheophytin a (after acidifying HCl), extracted with 90% acetone [43], were calculated in the suspension of POC > 1.6 μm, based on the amount of absorption for the wavelengths 663, 665 and 750 nm.

The concentration of non-volatile total (TOC) and dissolved (DOC = DOC < 0.45 μm) organic carbon and that of organic carbon contained in the water filtered through the GF/C filter were determined using a Shimadzu carbon analyzer TOC-5000 (mg $C \cdot dm^{-3}$). Before the analysis, the samples were acidified to the pH ≈ 2 using HCl 1:2 and oxygen was passed through them in order to remove CO_2.

The amount of absorption within the UV radiation range in the non-acidified samples filtered through the membrane filter was measured with a Shimadzu UV-1601-PC scanning spectrophotometer and 10-mm quartz cell. The relative aromaticity index for organic matter SUVA (Specific UV Absorbance) was calculated using the following formula:

$SUVA = Abs_{\lambda} \cdot 1000/DOC$, for $\lambda = 254$ nm [$dm^3 \cdot cm^{-1} \cdot (g\ C)^{-1}$].

The remaining hydrochemical examinations – temperature, color and water transparency, pH, dissolved oxygen, oxygen consumption (COD_{Mn}), biochemical oxygen demand (BOD_5) and total organic nitrogen (TON) – were performed according to the methodology by Hermanowicz *et al.* [15]. With regard to the critical values table [1], correlation coefficients between the parameters under study were determined.

RESULTS

T-POC

The content of T-POC were within the range from 3.13 mg C·dm^{-3} during the summer stagnation (June 2007) to 13.28 mg C·dm^{-3} during the autumn circulation (October 2006) in the water surface layer (1 m) of Modrzewiowy Pond (Fig. 1).

In the water bottom layer (5 m), the concentrations of T-POC changed from 4.96 mg C·dm^{-3} (October 2006) to 32.69 mg C·dm^{-3} (October 2007) (Fig. 2). The average concentration of this fraction was four times higher (21.03 mg C·dm^{-3}), and the percentage of T-POC in TOC – about twice higher (62%) than that at the depth of 1 m (Tab. 1).

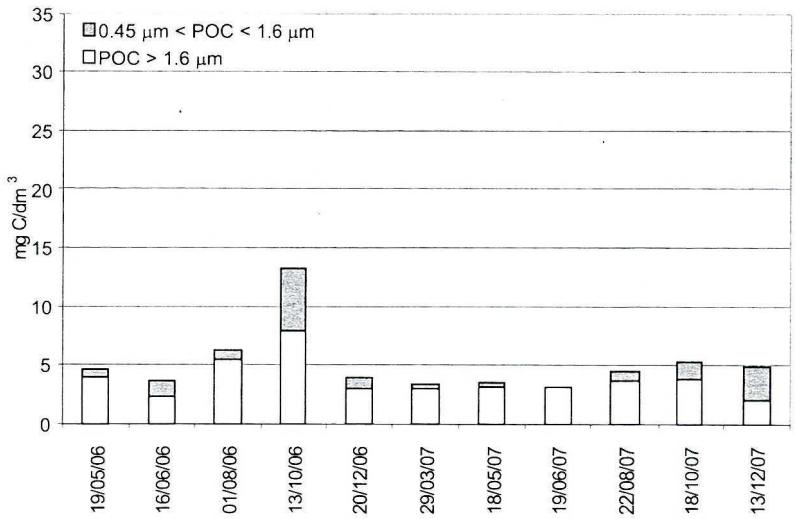

Fig. 1. Particulate organic carbon forms (POC) variability in the water surface layer (1 m) of Modrzewiowy Pond

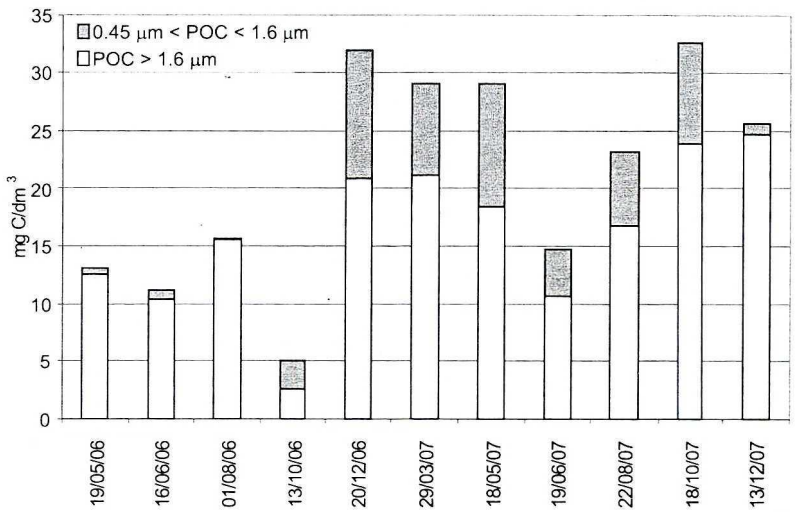

Fig. 2. Particulate organic carbon forms (POC) variability in the water bottom layer (5 m) of Modrzewiowy Pond

Table 1. The average values of measured parameters in water of Modrzewiowy Pond

Parameter		Surface (1 m)	Bottom (5 m)
TOC	[mg C·dm^{-3}]	14.77	32.20
T-POC		5.13	21.03
POC > 1.6 μm		3.73	16.12
0.45 μm < POC < 1.6 μm		1.40	4.90
DOC		9.63	11.18
DOC/TOC·100	[%]	67	38
T-POC/TOC·100		33	62
SUVA	[dm^3·cm^{-1}·(g C)$^{-1}$]	22.90	30.87
Chlorophyll a	[mg·m^{-3}]	74.26	75.61
Pheophytin a		24.91	94.39

POC > 1.6 μm

The fraction of particulate organic carbon released on the GF/C filter dominated in T-POC and averaged 73% and 77% of T-POC in the water surface and bottom layer, respectively. Its concentration varied from 1.96 mg C·dm^{-3} during the winter stagnation (December 2007) to 7.93 mg C·dm^{-3} during the autumn circulation (October 2006) (Fig. 1).

A well-marked increase in POC > 1.6 μm concentration in the water bottom layer was observed from December 2006. Its highest content occurred during the winter stagnation and amounted to 24.74 mg C·dm^{-3} (December 2007) (Fig. 2). The average concentration of this fraction was four times higher than at the depth of 1 m and amounted to 16.12 mg C·dm^{-3} (Tab. 1).

0.45 μm < POC < 1.6 μm

No fraction 0.45 μm < POC < 1.6 μm was recorded in the water surface layer in June 2007. A well-marked increase in its concentration occurred in the autumn-winter period and reached the maximum of 5.35 mg C·dm^{-3} (October 2006) (Fig. 1).

The average content of this fraction in the bottom water was about three times higher than at the depth of 1 m and amounted to 4.90 mg C·dm^{-3} (Tab. 1). The highest percentage in the T-POC was recorded at the beginning of the summer stagnation and it amounted to over 37% (May 2007) (Fig. 2). The highest amounts of the form 0.45 μm < POC < 1.6 μm were observed from the winter stagnation to the beginning of summer thermal stratification, and its maximum concentration – 11.09 mg C·dm^{-3} – occurred in December 2006.

DOC

The DOC fraction outnumbered the T-POC and constituted on average 67% of TOC in the water surface layer of Modrzewiowy Pond (Tab. 1). The concentration of DOC increased at the peak of the summer stagnation in the first year of investigation (maximally 11.73 mg C·dm^{-3}), and in the second year of investigation it remained at a similar level (Fig. 3). The autumn circulation caused a decrease and almost completely equalized of the DOC amount in the water column. Its lowest concentration (8.16 mg C·dm^{-3}) was recorded in October 2006.

The highest content of DOC (13.97 mg C·dm^{-3}) was recorded near the bottom in March 2007 (Fig. 3). Comparing average concentrations of DOC at the surface and over the bottom, no significant differences were found, in contradistinction to each of the POC forms

under study. The DOC concentration averaged twice lower than the T-POC, and its percentage in the TOC amounted on average to only 38%, in the water bottom layer (Tab. 1).

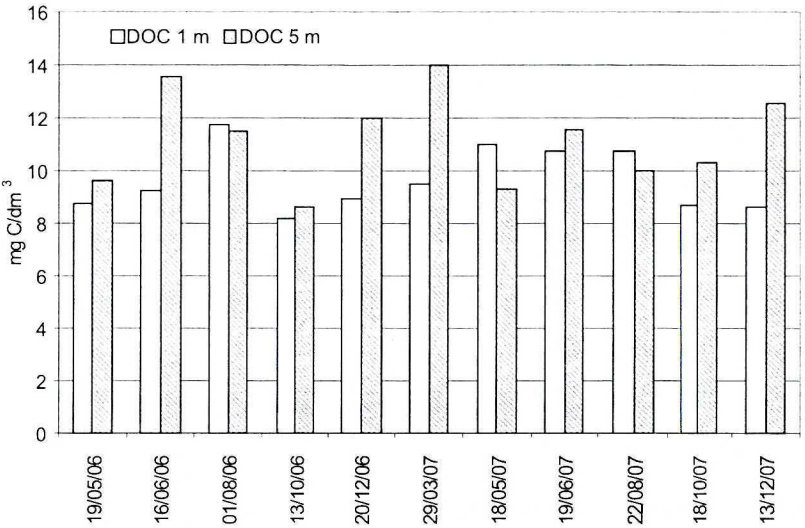

Fig. 3. Dissolved organic carbon (DOC) concentrations in the water of Modrzewiowy Pond

SUVA

At the depth of 1 m the values of the SUVA index were characterized by a low variability. During the whole period of study the values of this parameter ranged from 20.57 $dm^3 \cdot cm^{-1} \cdot (g\ C)^{-1}$ during the summer stagnation (August 2007) to 26.09 $dm^3 \cdot cm^{-1} \cdot (g\ C)^{-1}$ during the autumn circulation (October 2006) (Fig. 4).

A similar situation occurred in the water bottom layer. The variations were observed in the spring (March 2007) and during the summer stagnation (June 2007), when the SUVA values increased to 77.45 and to 60.16 $dm^3 \cdot cm^{-1} \cdot (g\ C)^{-1}$, respectively (Fig. 4).

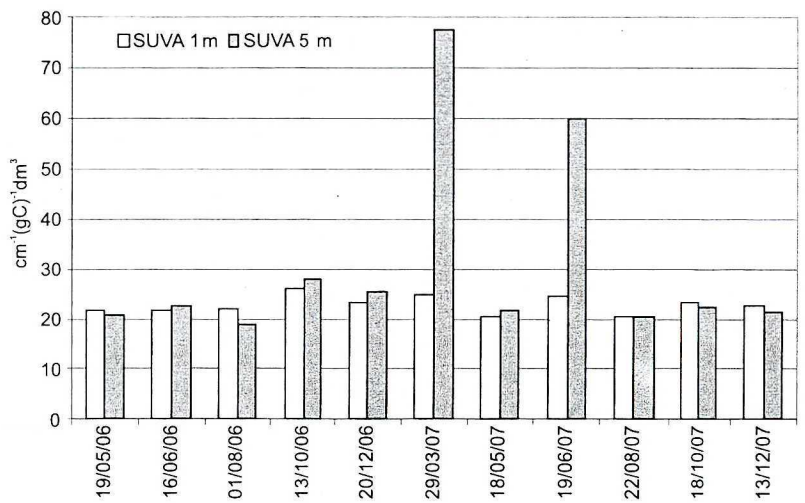

Fig. 4. SUVA index values in the water of Modrzewiowy Pond

Chlorophyll a

In the first year of the investigation, an increasing tendency in the concentration of chlorophyll was observed from the beginning of the summer stagnation (48.47 mg·m^{-3}) to the winter stagnation (80.06 mg·m^{-3}) (Fig. 5). The maximum concentration of this dye – 216.38 mg·m^{-3} – was observed in the summer of 2007. A repeated increase in the concentration of chlorophyll was recorded at the peak of the summer stagnation and it amounted to 79.39 mg·m^{-3}. The lowest amount of chlorophyll (20.78 mg·m^{-3}) was observed during the winter stagnation of 2007 (Fig. 5).

A distinct increase in the concentration of chlorophyll in the water bottom layer was recorded: from 54.26 mg·m^{-3} (May 2006) to 112.27 mg·m^{-3} (June 2006) and from 26.9 mg·m^{-3} (May 2007) to 144.61 mg·m^{-3} (October 2007) (Fig. 5). During the summer stagnation in 2006 and 2007 and during the autumn circulation in 2007, a distinctly higher amount of chlorophyll was observed in the bottom water of the reservoir than at the depth of 1 m.

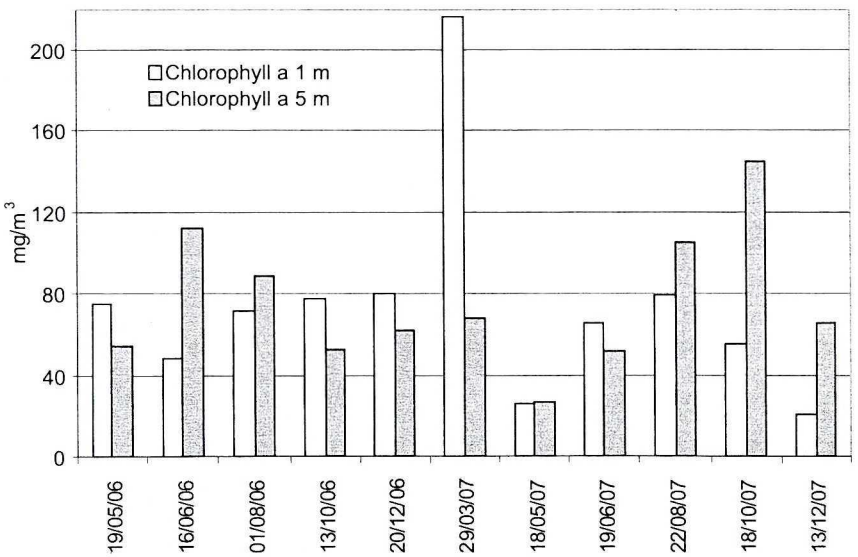

Fig. 5. Chlorophyll a concentrations in the water of Modrzewiowy Pond

Pheophytin a

The concentrations of pheophytin did not vary much at the depth of 1 m. Its lowest and highest content was recorded during the autumn circulation and amounted to 12.24 mg·m^{-3} (October 2007) and 58.67 mg·m^{-3} (October 2006), respectively (Fig. 6).

Higher differences in the concentration of pheophytin were recorded in the bottom layer of Modrzewiowy Pond – the minimum (29.90 mg·m^{-3}) was observed in October 2006, and maximum (150.62 mg·m^{-3}) – during the winter stagnation of 2007 (Fig. 6). The average content of this dye was four times higher than at the depth of 1 m and amounted to around 95.00 mg·m^{-3} (Tab. 1).

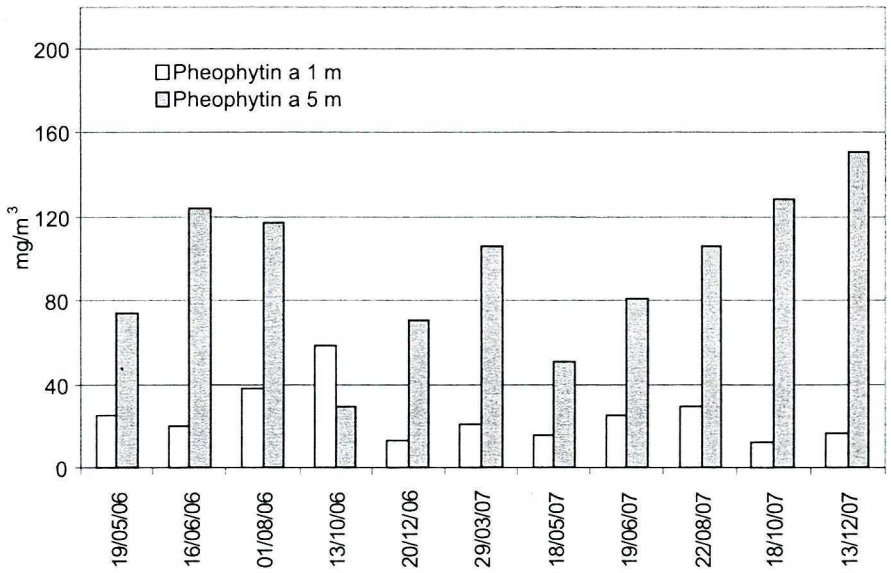

Fig. 6. Pheophytin concentrations in the water of Modrzewiowy Pond

DISCUSSION

Unfavorable – mostly anthropogenic – trends in the transformations of small water reservoirs cause a necessity to protect them and prevent a loss of quantitative and qualitative parameters of these ecosystems [41, 44, 45].

The variations in the POC fraction in the reservoir waters result from increase and decrease in the primary production [32, 33, 38], variations of zooplankton numerical force [26] and bacterial biomass [5] and the intensity of the process of organic matter decomposition [34].

A very high significant dependence between POC > 1.6 μm ($r = 0.904$, $p = 0.01$, $n = 11$), and between 0.45 μm < POC < 1.6 μm ($r = 0.884$, $p = 0.01$, $n = 11$) and T-POC (Tab. 2) indicates a high influence of the two fractions on the total pool of POC in the waters of Modrzewiowy Pond.

No significant correlation between the content of POC > 1.6 μm and the concentration of chlorophyll was found throughout the period of investigations (Tab. 2). This was likely due to low phytoplankton biomass in the suspension under investigation, or else high influence of the secondary production on the total concentration of the particulate form of organic carbon [49]. Similarly, no correlation between the content of POC > 1.6 μm and the concentration of chlorophyll was observed in the waters of Lake Długie during its recultivation by means of PAX-18 [32], when the content of POC connected with the primary production decreased.

The content of 0.45 μm < POC < 1.6 μm was negatively correlated with the concentration of DOC ($r = -0.611$, $p = 0.05$, $n = 11$) at the depth of 1 m (Tab. 2). According to Wetzel and Manny [48], it could have been caused by the presence of heterotrophic bacteria, for which DOC is the most available form of organic carbon. The activity of bacteria (0.45 μm < POC < 1.6 μm) influenced the content of dissolved organic matter

Table 2. Relationships between measured parameters in water of Modrzewiowy Pond (in parentheses – number, n)

Relationship	Surface (1 m)	Bottom (1 m)
POC > 1.6 μm / T-POC	r = 0.905 p = 0.01 (11)	r = 0.919 p = 0.01 (11)
0.45 μm < POC < 1.6 μm / T-POC	r = 0.885 p = 0.01 (11)	r = 0.783. p = 0.01 (11)
POC > 1.6 μm / Chlorophyll a	insignificant (11)	insignificant (11)
0.45 μm < POC < 1.6 μm / DOC	r = -0.611 p = 0.05 (11)	insignificant (11)
0.45 μm < POC < 1.6 μm / BOD_5	r = -0.691 p = 0.05 (10)	insignificant (10)
Chlorophyll a / COD_{Mn}	r = 0.701 p = 0.02 (11)	insignificant (11)
Chlorophyll a / color	r = 0.595 p = 0.1 (11)	r = 0.560 p = 0.1 (11)
Chlorophyll a / TON	r = 0.921 p = 0.01 (11)	r = -0.630 p = 0.1 (10)
Chlorophyll a / dissolved oxygen	r = 0.718 p = 0.02 (11)	–
Pheophytin a / T-POC	r = 0.854 p = 0.01 (11)	insignificant (11)
Pheophytin a / DOC	insignificant (11)	r = 0.619 p = 0.05 (11)
DOC / BOD_5	r = 0.744 p = 0.02 (10)	insignificant (10)
DOC / pH	insignificant (11)	r = -0.626 p = 0.05 (11)
SUVA / Abs_{254}	insignificant (11)	r = 0.984 p = 0.01 (11)
T-POC / COD_{Mn}	r = 0.741 p = 0.01 (11)	insignificant (11)

by enabling its reduction – the so called microbiological loop [4]. A similar dependence was recorded by Parszuto [32] in the metalimnion of recultivated Lake Długie. A significant negative dependence between the fraction 0.45 μm < POC < 1.6 μm and BOD_5 (r = -0.691, p = 0.05, n = 10) is the confirmation of the importance of the microbiological loop for the reduction of easily available organic matter in the waters of Modrzewiowy Pond at the depth of 1 m (Tab. 2). The values of BOD_5 in the water surface layer were relatively low and usually ranged from 3.00 mg $O_2 \cdot dm^{-3}$ to around 5.00 mg $O_2 \cdot dm^{-3}$.

The level of chlorophyll shows intensity of the photosynthesis process and the content of phytoplankton biomass in the water under study [21]. The average concentrations of this dye (above 70 mg$\cdot m^{-3}$) (Tab. 1) in the total mass of the water, indicates that Modrzewiowy Pond was characterized by a very high primary production and trophy [3]. Increased values of this parameter observed during summer stagnations were connected with the growth of the primary production. The growth of the intensity of this process (and an increase in the content of chlorophyll a) increased the amount of sparingly de-

composable organic matter (oxygen consumption) and water color, as well as the content of organic nitrogen and oxygen dissolved in the water surface layer of the reservoir under study (positive dependence between the concentration of chlorophyll and the mentioned above parameters: r = 0.595-0.921, p = 0.1–0.01, n = 11) (Tab. 2). The high concentration of chlorophyll in the water bottom layer of Modrzewiowy Pond was influenced by a constant presence of bacteriochlorophyll ($Abs_{665}/Abs_{655} < 1$) – mainly d ($Abs_{407}/Abs_{466} > 1$) (Tab. 3), the maximum absorption of which falls at 407 nm [17].

Table 3. Bacteriochlorophyll (quotient $Abs_{665}/Abs_{655} < 1$) in bottom water of Modrzewiowy Pond (bacteriochlorophyll d – $Abs_{407}/Abs_{466} > 1$)

	19/05/06	16/06/06	01/08/06	13/10/06	20/12/06	29/03/07	18/05/07	19/06/07	22/08/07	18/10/07	13/12/07
Abs_{665}/Abs_{655}	0.51	0.48	0.50	0.60	0.46	0.80	0.56	0.69	0.53	0.43	0.63
Abs_{407}/Abs_{466}	3.52	4.74	3.07	1.83	3.39	1.75	2.85	2.93	3.84	3.85	2.03

Concentrations of pheophytin were characterized by a higher variability than those of chlorophyll. Pheophytin was a result of chlorophyll decomposition therefore its amount could affect the intensity of the process of the organic matter decomposition [31]. A markedly lower concentration of pheophytin was recorded in the water surface layer than in the bottom. A highly significant correlation between the concentration of this dye and that of the fraction T-POC (r = 0.854, p = 0.01, n = 11), observed at the depth of 1 m (Tab. 2), indicates a significant effect of dead organic matter on the total amount of organic suspension in the waters of Modrzewiowy Pond.

Low concentrations of pheophytin in the water surface layer may indicate an intensification of the process of organic matter decomposition. However, the formation of shallow epilimnion during the summer stagnation, causing accelerated sedimentation of organic matter, seems to be more likely [37]. A similar dependence was found by Parszuto *et al.* [36] during the investigation of the waters of Lake Isąg, where relatively shallow epilimnion favored the sedimentation of organic suspension. During the summer stagnation, in the waters of Modrzewiowy Pond, a high stratification: shallow epilimnion (1–2 m) and sharp thermocline, often reaching the bottom (maximally 7.3°C, between the 2nd and 3rd meter of depth, in June 2006) was observed. In the bottom layer of the water of Modrzewiowy Pond, the concentration of pheophytin was correlated significantly with the concentration of DOC (r = 0.619, p = 0.05, n = 11) (Tab. 2). This testifies to the influence of decomposed there particulate organic matter (originating from the primary production) on the total pool of the dissolved fraction of carbon.

The DOC concentrations recorded in the reservoir under study were typical of eutrophic waters [11, 47]. Average DOC concentrations in the surface layer (9.63 mg $C \cdot dm^{-3}$) and the bottom layer (11.18 mg $C \cdot dm^{-3}$) of the water of Modrzewiowy Pond were relatively high in comparison with other lakes, e.g. in Lake Wigry – 3.54 mg $C \cdot dm^{-3}$ [12], or with highly eutrophized Lake Starodworskie – 7.31 mg $C \cdot dm^{-3}$ [35]. Tandyrak *et al.* [46] found that among all studied ponds situated in Kortowo and areas adjacent to it, Modrzewiowy Pond exhibited the highest DOC content during the summer stagnation (36.5 mg $C \cdot dm^{-3}$). In the years 2006–2007 the waters of this reservoir were characterized

by an increase in the concentration of DOC in the surface layer during summer stagnations. It could have been caused by intensive primary production in the reservoir, which, as proved by Moran and Estrada [30], can be accompanied by a growth of the concentration of this organic carbon fraction. The primary production was the source of easily decomposable dissolved organic matter in the surface layer of the water of Modrzewiowy Pond – a positive dependence between DOC and BOD_5 ($r = 0.744$, $p = 0.02$, $n = 10$) (Tab. 2) was found at the depth of 1 m, which proves a relatively high concentration of easily decomposable organic matter in this carbon fraction.

According to Guziur [13], clay-pits are characterized by relatively warm, turbid and poorly oxygenated water. Oxygen deficiencies in the deeper layers of the water of Modrzewiowy Pond irrespective of the season of the year, very low water transparency measured with the Secchi disk (0.50–1.9 m, on average 0.80 m), and an extremely high color (from 30 mg $Pt \cdot dm^{-3}$ at the surface to 240 mg $Pt \cdot dm^{-3}$ over the bottom) were recorded during the investigations. Such a high color can be caused by a high content of humus substances (SH), making up the composition of the dissolved carbon fraction, which may cause a decrease in the water transparency [16]. SH are one of the most important groups of natural organic substances in water ecosystems [6] and constitute 60–80% of the total mass of organic substances [11]. Gjessing [8] proved that the water color changed from yellow to brown with the growth of the concentration of humus compounds. In turn, Frimmel [6] found that dissolved humus acids were responsible for the color of lake waters in 75–85%. SH may cause a decrease in the water reaction (pH) [16], causing its acidification. Such a phenomenon was observed in the bottom layer of the water of Modrzewiowy Pond, where an interdependence between the increase in the concentration of DOC and the decrease in pH ($r = -0.626$, $p = 0.05$, $n = 11$) was found (Tab. 2). The pH values were low and ranged from 5.74 to 6.90, like in other urban small water reservoirs of this type [45].

The observed low variability of the DOC content in the surface and bottom layers of the water of Modrzewiowy Pond was caused by a high share of slow-biodegradable compounds in this fraction [39].

An enormous variety of organic substances occurring in nature requires advanced analytical techniques. Various indices are used to determine the contents of organic substances in water. However, the qualitative evaluation is clearly more troublesome. The application of absorbance specific in ultraviolet – SUVA – in the evaluation of the quality of the examined water can be a solution to this problem [29]. Absorbance UV_{254} is shown mostly by humus acids, tannins, lignins, phenols, as well as other organic compounds which contain the aromatic ring in their composition. However, it is not showed by alcohols, ethers, sugars, carboxylic acids and their derivatives and many others [2].

During the whole research period, high values of the SUVA parameter were recorded in the waters of Modrzewiowy Pond. A well-marked growth of this index was observed over the bottom in the spring of 2007. It could be caused by the inflow of dead organic matter to bottom waters (e.g. vegetal matter in which the concentration of pheophytin was determined), which was then decomposed to simpler compounds. Substances formed this way could enrich the pool DOC, the well-marked increase of which was observed in that time. A similar situation was repeated three months later in June.

During the whole research period, the qualitative changes (a highly significant positive correlation between SUVA and Abs_{254}, Tab. 2) and quantitative DOC ones in the wa-

ter bottom layers were due to increased sedimentation of POC from the surface layer and its decomposition, mostly under the conditions of oxygen deficiency. Apart from high primary production; steep scarp covered with deciduous trees on the shore of Modrzewiowy Pond and wooded islets in its central part were an important source of organic matter. It is allochthonous organic matter in the form of falling and decaying leaves [50]. That is why a high positive dependence between T-POC and COD_{Mn} ($r = 0.741$, $p = 0.01$, $n = 11$, Tab. 2) was found. The values of COD_{Mn} were high and ranged from 26.56 mg $O_2 \cdot dm^{-3}$ to 144.00 mg $O_2 \cdot dm^{-3}$ over the bottom (around 60.00 mg $O_2 \cdot dm^{-3}$ on average). Mołczan *et al.* [29] found that natural waters with high values of SUVA are characterized by a high content of hydrophobic, aromatic and large-molecular fractions of dissolved organic carbon, while waters with low values of this parameter contain mostly non-humus, hydrophilous substances with small molecular masses. A low variability of the SUVA parameter, both in the surface layer of the water of Modrzewiowy Pond and in its bottom layer proves a relatively constant amount of compounds easily absorbing UV radiation.

The ratio of total organic carbon (TOC) to total organic nitrogen (TON) > 17 indicates the allochthonous origin of organic matter [19]. An increase in allochthonous organic matter during the autumn circulation and at the beginning of the summer stagnation, when the TOC/TON values oscillated around 40, was observed in the waters of Modrzewiowy Pond. Other studies proved the autochthonous origin of organic matter in this reservoir.

CONCLUSIONS

The quantitative and qualitative investigations of organic matter in the waters of Modrzewiowy Pond classify it as highly eutrophic and indicate mostly autochthonous origin of organic substances cumulated in. Small changes in the SUVA index indicate a low variability of the quantity of slow-decomposable (high-molecular) compounds in the waters of this reservoir.

The high TOC concentration, resulting mainly from the high share of POC in TOC and high values of the SUVA parameter and concentrations of chlorophyll a and pheophytin a, show a significant influence of the primary production (phytoplankton and bacterioplankton) and the secondary production on the quantity and quality of organic matter in the reservoir under study.

The possibility of reducing the trophy of the waters of Modrzewiowy Pond, and, consequently, the quantity of organic matter by means of bacterial-enzymatic biopreparation is worth considering.

REFERENCES

[1] Bąk I., I. Markowicz, M. Mojsiewicz, K. Wawrzyniak: *Statystyka w zadaniach*, cześć 1, Wydawnictwa Naukowo-Techniczne, Warszawa 2002.

[2] Brenton R.W.: *New UV method added to the organic Chemistry Program Catalog*, National Water Quality Laboratory Newsletter, **7**, 3 (1999).

[3] Carlson R.E.: *A trophic state index for lakes*, Limnol. Oceanogr., **22**, 361–369 (1977).

[4] Chróst R.J.: *Znaczenie procesów mikrobiologicznych dla intensywności występowania symptomów eutrofizację wód*, [in:] M. Zalewski (red.), Procesy biologiczne w ochronie i rekultywacji nizinnych zbiorników zaporowych, Biblioteka Monitoringu Środowiska, PIOŚ Łódź 1995, 71–84.

[5] Coveney M.F., R.G. Wetzel: *Biomass, production, and specific growth rate of bacterioplankton and*

coupling to phytoplankton in an oligotrophic lake, Limnology and Oceanography, **40**(7), 1187–1200 (1995).

[6] Frimmel F.H.: *Photochemical aspects related to humic substances*, Envir. Internat., **20**(3), 373–386 (1994).

[7] Gawrońska H., Cz. Hołdyński, K. Lossow, R. Mackowicz, B. Polakowski: *Charakterystyka przyrodnicza wodnych i torfowiskowych zagłębień terenowych miasta Olsztyna*, Opracowanie na zlecenie Zarządu Miasta Olsztyna, 1994.

[8] Gjessing E.T.: *Physical and chemical characteristic of aquatic humic*, Ann. Arbor., MI, Ann. Arbor. Sci. Pub. 1976, pp. 120.

[9] Głażewski R., K. Parszuto: *Optical properties of dissolved organic matter (DOM) in the recultivated lakes of Olsztyn*, Limnological Review, 2, 137–142 (2002).

[10] Głażewski R., G. Wiśniewski: *The effect of allochthonous organic matter on changes in optical properties of recultivated Lake Kortowskie waters*, Polish Journal of Natural Sciences, **23**(1), 110–120 (2008).

[11] Górniak A.: *Substancje humusowe i ich rola w funkcjonowaniu ekosystemów słodkowodnych*, Diss. Univ. Vars., 448, Białystok 1996.

[12] Górniak A., P. Zieliński: *Rozpuszczone związki węgla organicznego w Jeziorze Wigry*, [in:] B. Zdanowski, M. Kamiński, A. Martyniak (eds.), Funkcjonowanie i ochrona ekosystemów wodnych, Wyd. IRŚ Olsztyn 1999, pp. 141–151.

[13] Guziur J.: *Charakterystyka małych zbiorników wodnych i możliwości ich rybackiego zagospodarowania*, Zesz. Nauk. ART. Olsztyn, Rybactwo 16, 16–65 (1988).

[14] Haan de H.: *Impacts of environmental changes on the biogeochemistry of aquatic humic substances*, Hydrobiologia, 229, 59–71 (1992).

[15] Hermanowicz W., J. Dojlido, W. Dożańska, B. Koziorowski, J. Zerbe: *Fizyczno-chemiczne badanie wody i ścieków*, Arkady, Warszawa 1999.

[16] Hessen D.O., L.J. Tranvik (Eds): *Aquatic humic substances*, [in:] Ecology and Biogeochemistry, Springer 1998, Ecological Studies vol. 133, pp. 346.

[17] Hutorowicz A.: *Primary production of phytoplankton community, and concentration of chlorophyll and bacterio-chlorophyll in Lake Smolak (Mazurian Lakeland, Poland)*, Arch. Ryb. Pol., **6**(2), 197–208 (1998).

[18] Ilnicki P.: *Ekologiczne podstawy ochrony biotopów wód stojących*, Wiadomości melioracyjne i łąkarskie, 11, 295–298 (1987).

[19] Kajak Z.: *Hydrobiologia-limnologia. Ekosystemy wód śródlądowych*, PWN, Warszawa 2001.

[20] Kasprzak K.: *Ekologiczne znaczenie małych wód powierzchniowych dla otaczających ekosystemów lądowych*, Gospodarka Wodna, 4, 84–85 (1985).

[21] Kawecka B., P.V. Eloranta: *Zarys ekologii glonów wód słodkich i środowisk lądowych*, PWN, Warszawa 1994.

[22] Koc J., Z. Nowicki: *Czynniki kształtujące chemizm wód oczek w środowisku rolniczym*, [in:] Przyrodnicze i techniczne problemy ochrony i kształtowania środowiska rolniczego, II Ogólnopolska Konferencja Naukowa, Poznań 1997, 91–97.

[23] Koc J., S. Tucholski: *Śródpolne zbiorniki retencyjne jako metoda redukcji zanieczyszczeń obszarowych*, [in:] Rolnictwo polskie a jakość wody, ODR – RCEE Przysiek 1995, pp. 43–48.

[24] Koc J., A. Skwierawski, I. Cymes, U. Szperek: *Znaczenie ochrony małych zbiorników wodnych w krajobrazie przyrodniczym*, Wiadomości melioracyjne i łąkarskie, **45**, 2, 64–68 (2002).

[25] Kosturkiewicz A., M. Fielder: *Oczka wodne w eksploatacji systemów drenarskich na terenach bogato urzeźbionych*, Zesz. Nauk. AR Wrocław, Konferencje VIII, 266, 191–199 (1995).

[26] Lampert W., U. Sommer: *Ekologia wód śródlądowych*, PWN, Warszawa 1996.

[27] Matusiak R.: *Zbiorowiska roślinne śródpolnych oczek wodnych oraz zagłębień mokradłowych na Równinie Wełtyńskiej*, Zesz. Nauk. AR Szczecin, Rolnictwo, 173, 31–36 (1996).

[28] Mioduszewski W.: *Rola małych zbiorników wodnych w środowisku przyrodniczym*, Mat. Semin. IMUZ Falenty 1997, 40, 7–17.

[29] Mołczan M., M. Szlachta, A. Karpińska., A. Biłyk: *Zastosowanie absorbancji właściwej w nadfiolecie (SUVA) w ocenie jakości wody*, Ochrona Środowiska, **28**, 4, 11–16 (2006).

[30] Moran X.A.G., M. Estrada: *Phytoplanktonic DOC and POC production in the Bransfield and Gerlache Straits as derived from kinetic experiments of ^{14}C incorporation.* Deep-Sea Research II 49, 769–786 (2002).

[31] Mucha A., M. Rybak: *Zawartość chlorofilu w fitoplanktonie Jeziora Długiego*, Zesz. Nauk. ART w Olszt., Ochrona Wód i Rybactwo Śródlądowe, 9, 47–53 (1979).

[32] Parszuto K.: *Dynamika węgla organicznego w wodach jezior poddawanych różnym metodom rekultywacji*, Praca doktorska, Katedra Inżynierii Ochrony Środowiska, UWM, Olsztyn 2003.

[33] Parszuto K.: *POC, chlorophyll a and pheophytin a vertical distribution in restored Kortowskie lake (Poland)*, Limnological Papers, 3,79–88 (2008).
[34] Parszuto K., J. Grochowska: *Wpływ sztucznego napowietrzania z destratyfikacją na zmienność wybranych wskaźników zawartości materii organicznej w wodach Jeziora Długiego*, Zesz. Probl. Post. Nauk Rol., 505, 297–304 (2005).
[35] Parszuto K., E.A. Kaliszewska: *The evaluation of the trophy of selected Olsztyn lakes by means of indices of particulate organic carbon (POC) and dissolved organic carbon (DOC)*, Limnological Review, 7, 29–35 (2007).
[36] Parszuto K., M. Teodorowicz, J. Grochowska: *Relationship between organic carbon and other measures of organic matter in the waters of Lake Isąg*, Limnological Review, 6, 233–238 (2006).
[37] Patalas K.: *Punktowa ocean pierwotnej produktywności jezior okolic Węgorzowa*, Roczn. Nauk Roln., T. 77-B-1, 299–326 (1960).
[38] Pełechaty M., A. Pełechata, P. Niedzielski: *Spatial and temporal variability of TOC concentrations in a shallow and eutrophicated lake ecosystem (Lake Jarosławieckie, Wielkopolski National Park, Western Polanad)*, Polish Journal of Environmental Studies, **12**(5), 607–611 (2003).
[39] Pempkowiak J.: *Rozmieszczenie, pochodzenie i właściwości kwasów humusowych w Morzu Bałtyckim*, Ossolineum, Wrocław 1989.
[40] Ryszkowski L.: *Bariery biogeochemiczne*, [in:] Bariery biogeochemiczne w krajobrazie rolniczym, UAM 1990, pp. 168–181.
[41] Skwierawski A.: *Ocena stanu małych zbiorników wodnych na terenach wiejskich. Cz. II. Zastosowanie metody do oceny stanu małych zbiorników na Pojezierzu Olsztyńskim*, Zesz. Probl. Post. Nauk Rol., 506, 403–413 (2005).
[42] Solarski H.: *Układ stosunków wodnych w pagórkowatych zlewniach pojezierza mazurskiego*, Praca habilitacyjna, WSR Olsztyn 1967.
[43] *Standard Methods for the examination of water and wastewater*, American Public Health Association, Washington D.C., 1268 (1985).
[44] Surmacki A.: *Zagrożenia małych zbiorników śródpolnych na Pomorzu Zachodnim*, Chrońmy Przyrodę Ojczystą, **54**(6), 61–69 (1998).
[45] Tandyrak R., J. Grochowska: *Impact of the watershed development on the chemical properties of water in small reservoirs of the Olsztyn city*, Electronic Journal of polish Agricultural Universities (EJPAU), 10(1), 14 (2007).
[46] Tandyrak R., J. Grochowska, J. Dunalska: *Wpływ zagospodarowania terenu na parametry hydrochemiczne wód i osadów dennych małych zbiorników wodnych dzielnicy Kortowo w Olsztynie*, Zesz. Probl. Post. Nauk Rol., 505, 459–465 (2005).
[47] Thurman E.M.: *Multidisciplinary research-an experiment*, Environmental Science and Technology, A, **17**, 511 (1983).
[48] Wetzel R.G., B.A. Manny: *Seasonal changes in particulate and dissolved organic carbon and nitrogen in hardwater stream*, Arch. Hydrobiol., **80**(1), 20–39 (1977).
[49] Vincent W.F., M. Kumagai, C. Belzile, K. Ishikawa, K. Hayakawa: *Effects of seston on ultraviolet attenuation in Lake Biwa*, Limnology, 2, 179–184 (2001).
[50] Zieliński P, A. Górniak, K. Choroszewska: *Changes in water quality induced by the decomposition of plant detritus*, Acta Hydrobiol., **41**(6), 119–126 (1999).

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JAKOŚCIOWA I ILOŚCIOWA CHARAKTERYSTYKA MATERII ORGANICZNEJ W WODZIE MAŁEGO ZBIORNIKA

Celem badań była jakościowa i ilościowa charakterystyka materii organicznej w wodzie małego zbiornika, Modrzewiowego Stawu, za pomocą wskaźnika SUVA oraz form cząsteczkowego (POC) i rozpuszczonego węgla organicznego (DOC). Stężenie całkowitego węgla organicznego (TOC) i DOC ustalono za pomocą analizatora Shimadzu TOC-5000. Frakcję POC otrzymano z różnicy między TOC i DOC. W wodzie naddennej zbiornika zaobserwowano wysoką średnią koncentrację TOC (32,20 mg $C \cdot dm^{-3}$), wynikającą głównie z dużego udziału POC (21,03 mg $C \cdot dm^{-3}$) w TOC, wysokie wartości parametru SUVA (30,87 $dm^3 \cdot cm^{-1} \cdot (g\ C)^{-1}$) oraz stężenia chlorofilu a (75,60 $mg \cdot m^{-3}$) i feofityny a (94,39 $mg \cdot m^{-3}$). Wysokie wartości wskaźnika SUVA świadczyły o dużym udziale trudno rozkładalnych związków w puli DOC. Wykazano istotny wpływ produkcji pierwotnej oraz wtórnej na jakość i ilość materii organicznej w badanym zbiorniku.