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Vertical distribution of aldehydes and phytoplankton structure: a case study of urban lake

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Abstract: In water systems, both biologically and chemically synthesized molecules may reduce environmental quality and influence essential ecosystems structure and function. These substances include aldehydes from various sources, also those relates to the activities of primary producers. The focus of the study was vertical distribution of several aliphatic aldehydes and phytoplankton biomass in an urban lake in Poznań (Wielkopolska Lakeland, Poland) under human pressure. Water samples were collected from surface lake to bottom, every 2 m. Plankton was analyzed under inverted and epifluorescence microscopes. The biomass was estimated from microscopic measurements and cell volume of each species. Thirteen aldehydes and acetone were analyzed using gas chromatography with an electron capture detector after derivatization and extraction processes. Aldehydes concentrations varied between 32.7 and 346.2 μg L^{-1}. Formaldehyde, acetaldehyde and propanal were characterized by the highest concentration both at low and high phytoplankton biomass. Phytoplankton biomass included prokaryotic and eukaryotic cells, and ranged between 0.25 and 2.94 mg L^{-1}. Cryptophytes and diatoms were often the most important components of phytoplankton communities, although in some cases the haptophytes and dinophytes comprised a much higher proportion. Total aldehyde concentration was significantly correlated with total phytoplankton biomass (r=0.705, p <0.05), and even higher correlation was observed between acetone and phytoplankton biomass (r=0.917). This indicates phytoplankton as an important source of carbonyl compounds in surface waters. Thus, the knowledge of different aspects of their origin and distribution in the lake is important both in ecological research and in water management.

Introduction

Water ecosystems are naturally located at the lowest point in the field. For this reason, many substances of different nature reach them as runoffs and also from the air with precipitation and winds. These include both natural and anthropogenic aldehydes. Their natural presence in the environment is connected with the phenomena of photochemical transformations, life processes of plant and animal organisms and decomposition of organic matter (Lerdau et al. 1997). It is known that a significant part of aldehydes are formed in the troposphere by photochemical transformations, from where they can get to surface waters through wet or wind deposition. Among the aliphatic aldehydes formaldehyde, acetaldehyde, propanal, glyoxal and methyloglyoxal (ubiquitous in the aquatic environment and in the air) are most often identified (Czaplicka et al. 2014, Dąbrowska and Nawrocki 2013, Matsunaga et al. 2007, Myriokefalitakis et al. 2008, Polkowska et al. 2006, 2011, Zhu and Kieber 2019). Fossil fuel combustion and plastic degradation processes are important anthropogenic sources of aldehydes in the environment. From PET bottles made of commonly used polyethylene terephthalate, many aldehydes migrate to water. The increase in UV radiation and temperature influences the concentration of aldehydes, which may change water parameters and promote the development of bacterial microflora. Between 4.8 and 12.8 million tons of plastic are dumped into the world's seas and oceans each year (Dąbrowska et al. 2003, Ewender et al. 2003, Haward 2020).

Organic substances not directly involved in the growth, development and reproduction of organisms are called secondary metabolites. These metabolites in the environment can be actively biological and affect other organisms. Whittaker (1972) called them allelochemicals, emphasizing that the phenomenon of allelopathy is common in plant communities and often forms quantitative relationships between species. In aquatic ecosystems allelopathic compounds are probably constantly released into the environment. These compounds are not attributed a significant role in metabolic processes and growth of phytoplankton. As secondary metabolites, they are rather an element of the chemical defense mechanism against the organisms' feeding from higher trophic levels. They can also act as signal substances or be a relic of evolutionary process.

These substances may be released during death or mechanical disturbance of cell membranes and cell protoplasms, and may be used as a food material for microorganisms. Many phytoplankton species have been shown to be capable of producing and releasing secondary metabolites. These are, e.g., blue-green algae, dinophytes, chrysophytes, green algae (Hansen et al. 2004, Ianora and Miralto 2010, Jüttner 1984, Leflaive and Ten-Hage 2007, 2009, Żak and Kosakowska 2015) and their production does not seem to be related to the size of organisms (Jakubowska and Szeląg-Wasielewska 2015, Śliwińska-Wilczewska et al. 2018).

The identified allelochemicals belong to various chemical types such as sulphur compounds, polyacetylenes, alkenes, aldehydes, ketones, alcohols, and oligopeptides. The recognition of their chemical structure requires sophisticated analytical methods and the main problem in the determination and isolation of allelopathic compounds is their production in very small quantities (Jüttner 1981, 1984, Gross 2003, Grabowska and Mazur-Marzec 2016). Potential biotic sources of low-molecular-weight aldehydes have not yet been sufficiently identified even though their abiotic photochemical production is well quantified. Aldehydes and ketones have been noticed already in the past century and were associated in the marine environment mainly with diatoms, haptophytes and dinophytes, while in fresh waters with chrysophytes. They were also found in cultures of microorganisms, e.g., green algae in quantities depending on the species under study (Hansen et al. 2004, Jalliffier-Merlon 1991, Jüttner 1981, Ribalet et al. 2014, Żak and Kosakowska 2015).

The aim of the study was to recognize the concentration and distribution of several low-carbon aliphatic aldehydes in an urban, medium-sized lake. Additionally, acetone was also analyzed because, as it was noticed earlier, this ketone often occurs in water together with formaldehyde and acetaldehyde. It was assumed that the presence of aldehydes may be a signal of the quality of habitat conditions for primary producers. The total concentration and concentration of individual aldehydes in the lake water column were considered, depending on the sampling depth and concentration of phytoplankton biomass. Two periods were selected for the analysis of these relationships: one with very low (late autumn) and the other with relatively high (spring) phytoplankton biomass. Attempts were made to determine the potential biological source of aldehydes. This information is necessary for full recognition of the carbon balance and may eventually give additional insight into the lake carbon cycle.

Material and methods

Sample collection

The research concerned Lake Strzeszyńskie located in the headwater of small river Bogdanka within the city boundaries of Poznań (52°28'N, 16°49'E, Wielkopolska District; mid-western Poland). This urban lake covers an area of 35 ha, with a maximum depth of 17.8 m and a mean depth of 8.0 m and is subject to multiple human pressure: recreation, fishing, agriculture, and urbanization. The lake is of natural origin with a water volume of 2.8 million cubic meters (Szeląg-Wasielewska et al. 2015). Water samples for the chemical and biological analysis were collected in the pelagic zone of the Lake Strzeszyńskie, at the surface water and the depth of 2, 4, 6, 8, 10, 12, and 14 m in mid-December 2011 (late autumn) and in mid-April 2012 (spring). A TOŃ apparatus was used to collect samples at various depths throughout the water column. For aldehyde analyses the samples were preserved immediately at the site with copper sulphate solution and for phytoplankton either with buffered formaline (for research on picophytoplankton <2 µm) or with Lugol's solution (for research on the larger size groups of phytoplankton >2 µm), and kept in darkness at 4ºC until analysis. Water temperature and soluble oxygen concentration were measured with an YSI meter in the whole vertical column at 1-metre intervals.

Laboratory and microscopy analyses

Aldehydes (C1–C10, glyoxal and methylglyoxal) and acetone were analyzed by an efficient and sensitive methods based on a preliminary derivatization process with O-(2,3,4,5,6-pentafluorobenzyl) hydroxylamine and separation of the created oxymes by gas chromatography in the configuration with electron capture detector (GC/ECD). Gas chromatography GC 8000 series (Fisons Instruments) equipped with 63Ni electron capture detector (ECD, Fisons Instruments) and Chromatography Station for Windows system for collecting and processing the chromatographic data (CSW, Version 1,7 Eval, Build 270598, the Czech Republic) were used. A list of the studied carbonyl compounds and their detection limits is presented in Table 1. The details of aldehyde analysis were described earlier (Dąbrowska et al. 2003, Dąbrowska and Nawrocki 2013, Dabrowska et al. 2014).

Phytoplanktonic organisms were identified to the species level or, if this was impossible, they were only assigned to a genus. The identification of the phytoplankton was based on the current literature. The samples were viewed and counted at more than one magnification (100×, 200×, 400×, 1000×) depending on the size of the phytoplankton present. To reach the recommended precision level of ±20% or ±10%, between 100 or 400 units of algae taxon per sample were counted (Lund et al. 1958). The organisms larger than 2 µm were counted under an inverted microscope after sedimentation in settling chambers of 14 ml in volume, according to the method by Wetzel and Likens (2000). The organisms smaller than 2 µm were determined by epifluorescence microscopy, using instrumentation and protocols similar to those previously reported (MacIsaac and Stockner 1993, Szeląg-Wasielewska 2004). Phytoplankton is only a part of the suspension retained on membrane filters, therefore the volume of living cells was used to evaluate the biomass of phytoplankton. The biovolume of each species was calculated on the basis of cell shape, size, and number, while their biomass was expressed as wet weight assuming that the volume of 10^6 µm^3 is equivalent to 1 µg. Phytoplankton taxonomic groups were considered as the dominant if they accounted for more 50% of the total phytoplankton biomass. Statistical calculations were made using Statistica 8.0 software. The correlation was considered as statistically significant at the $p<0.05$ level.

Results

In December 2011, Lake Strzeszyńskie was no thermally and chemically stratified, but in April 2012, three layers were distinguished in the pelagic zone of the lake. The upper well oxygenated and relatively warm layer (epilimnion) was separated from the lower, partially almost anoxic and the cooler layer (hypolimnion) by transition zone (metalimnion). The large thickness of the epilimnion, i.e., 9 m, indicates the beginning of water stratification (Fig. 1). Water temperature and dissolved oxygen concentration along the depth profile were significantly correlated with the total aldehyde concentration. The correlation coefficients were r=0.672 and r=0.801, respectively.

Most of the examined aldehydes were found at all depths and in both months analyzed. The total amount of aldehydes in December varied widely from 32.7 μg L^{-1} to 337.3 μg L^{-1} and in April from 160.7 μg L^{-1} to 346.2 μg L^{-1}. The average values for these months were 138.2 μg L^{-1} and 250.2 μg L^{-1} respectively, and maximum to minimum aldehyde concentration ratio in the water column was about 10 and 2, respectively. Formaldehyde, acetaldehyde and propanal had the highest concentrations in both periods. Most of the remaining aldehydes, e.g., pentanal,

Table 1. List of studied aldehydes and limit of detection

Compound	IUPAC name	Molecular weight g/mol	Limit of detection (LOD) ng L^{-1}
Formaldehyde	Methanal	30.03	2.3
Acetaldehyde	Ethanal	44.05	5.1
Propionalaldehyde	Propanal	58.08	6.3
Butyraldehyde	Butanal	72.11	3.2
Valeraldehyde	Pentanal	86.13	2.1
Caproaldehyde	Hexanal	100.16	4.3
Enanthaldehyde	Heptanal	114.19	8.3
Caprylaldehyde	Octanal	128.21	2.1
Pelargonaldehyde	Nonanal	142.24	1.7
Caprinaldehyde	Decanal	156.20	2.6
Benzoic aldehyde	Benzaldehyde	106.12	3.3
Glyoxal	Ethanedial	58.04	5.4
Methylglyoxal	2-oxopropanal	72.06	1.5
Acetone	Propanone	58.08	6.8

IUPAC – International Union of Pure and Applied Chemistry

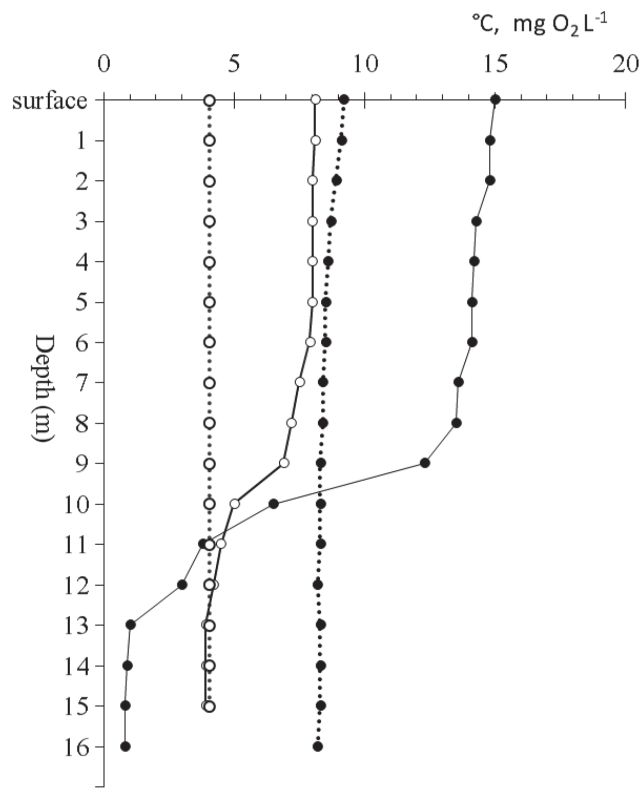

Fig. 1. Depth profile for temperature (open circles; °C) and oxygen concentration (dark circles; mg O_2 L^{-1}) in December (dashed line) and April (solid line)

heptanal, glyoxal, and methyglyoxal were present in 3–4 times higher concentrations in April than in December. In April, nonanal and decanal were also found, which in December were at undetected levels. The average concentration of acetone in the water column was 3 times higher in April than in December (Table 2).

Formaldehyde in April was characterized by similar concentrations at the studied depths, except for 8 m, where its concentration was higher – 126.67 μg L^{-1}. In December, it remained at a similar level to the depth of 10 m and then rapidly decreased several times. The concentrations of acetaldehyde and propanal generally decreased gradually as the depth increased. Only in April, in the upper part of the water column, at the depth of 4 m, the drop in propanal concentration was rapid, as it reached 12.8 μg L^{-1}. Thus, the neighboring depths were characterized by propanal concentration 7–8 times higher (Fig. 2, Fig. 3).

In the pelagial of Lake Strzeszyńskie occurred a significant correlation between the concentration of total aldehydes and total phytoplankton biomass (r=0.705). Among the thirteen aldehydes six were significantly positively correlated with biomass. They were followed by methylglyoxal (r=0.897), glyoxal (r=0.843), formaldehyde (r=0.772), heptanal (r=0.722), nonanal (r=0.657), and pentanal (r=0.649). The highest correlation coefficient was found for acetone and phytoplankton biomass (r=0.917).

Phytoplankton biomass included prokaryotic cells, such as cyanobacteria and eukaryotic cells representing cryptophytes, dinophytes, diatoms, chlorophytes, euglenophytes, haptophytes, and green algae. In December, the biomass was low varying from 0.25 mg L^{-1} to 0.42 mg L^{-1}, and its maximum was at 4 m depth. In deeper layers it gradually decreased to the lake bottom. This month, cryptophytes dominated (58.2–73.4%) in the whole water column (Fig. 4). The most important species that formed the phytoplankton biomass are representatives of the genus *Cryptomonas*, including *C. ovata* Ehrenberg and *C. marssonii* Skuja.

Table 2. Concentration of aldehydes compounds and acetone (μg L^{-1}) within the water column of Lake Strzeszyńskie

Compound	December		April	
	Min-max	Mean	Min-max	Mean
Formaldehyde	7.54–52.35	35.86	76.67–126.67	92.73
Acetaldehyde	4.08–93.76	28.02	19.16–46.36	32.1
Propanal	5.31–128.75	40.62	6.33–94.38	48.57
Butanal	1.92–13.47	4.41	1.89–7.63	4.97
Pentanal	n.d. –10.83	4.13	6.53–16.11	10.28
Hexanal	2.78–15.61	7.01	8.29–12.68	10.18
Heptanal	5.0–8.94	7.15	18.33–26.67	21.34
Octanal	n.d.–6.07	3.31	n.d.	n.d.
Nonanal	n.d.	n.d.	2.5–16.25	9.32
Decanal	n.d.	n.d.	n.d.–8.47	1.06
Benzaldehyde	n.d.–2.66	1.79	n.d.	n.d.
Glyoxal	0.31–4.82	2.36	1.55–12.82	7.91
Methylglyoxal	1.73–4.87	3.51	5.2–20.65	11.76
Acetone	2.77–8.23	4.66	4.85–17.38	12.79

n.d. – not determined – below the limit

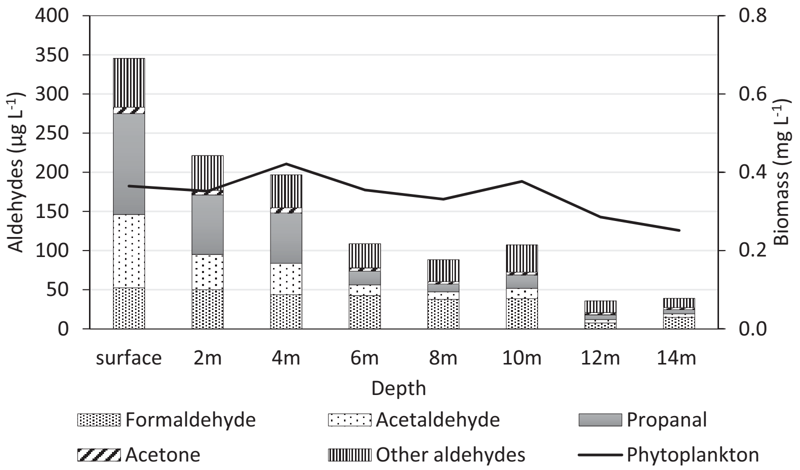

Fig. 2. Concentration of aldehydes compounds, aceton (bars) and total biomass of phytoplankton (line) at study depth in Lake Strzeszyńskie in December

In April, the average phytoplankton biomass in the water column was more than 5 times higher than in December ranged between 0.28 and 2.94 mg L^{-1}, and its maximum was at surface. In hypolimnion it clearly decreased to the lake bottom. Within the water column, diatoms and haptophytes cells contribute substantially to total phytoplankton biomass, respectively 20.4–57.0% and 16.7–36.4%, excluding the depth of 10 m, 12 m and 14 m, when a higher proportion of dinophytes, cryptophytes or cyanobacteria was observed. Cyanobacteria made a relatively large contribution to biomass in the deeper part of the hypolimnion – *Pseudanabaena* species accounted for 27% of the biomass (Fig. 5). The most important taxons in terms of biomass this month were the centric diatoms and nano- and microplanktonic flagellets: *Chrysochromulina parva* Lackey, *Plagioselmis lacustris* (Pascher & Ruttner) Javornicky, *Gymnodinium fuscum* (Ehrenberg) F. Stein.

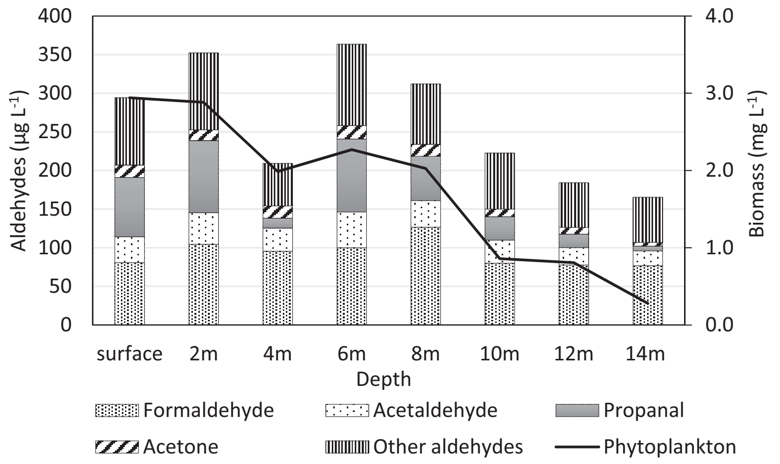

Fig. 3. Concentration of aldehydes compounds, acetone (bars) and total biomass of phytoplankton (line) at study depth in Lake Strzeszyńskie in April

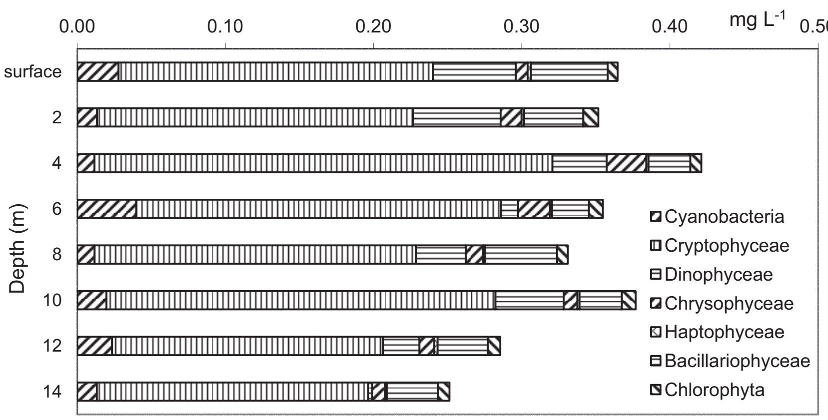

Fig. 4. Vertical distribution in biomass (mg L^{-1}) of taxonomic groups of phytoplankton in Lake Strzeszyńskie in December

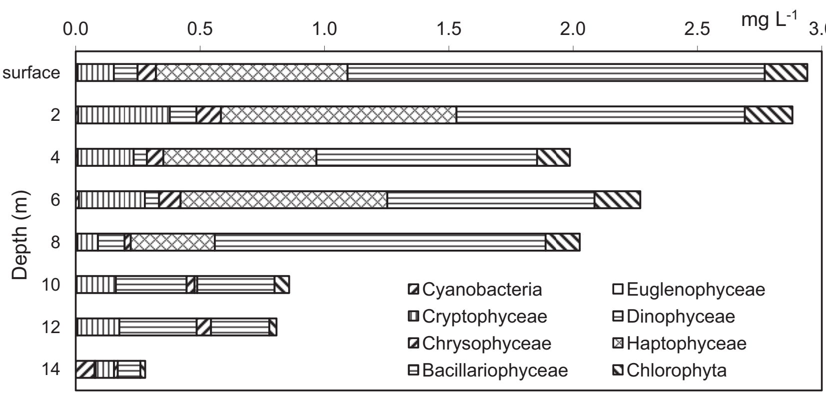

Fig. 5. Vertical distribution in biomass (mg L^{-1}) of taxonomic groups of phytoplankton in Lake Strzeszyńskie in April

Discussion

The research showed that the concentration of aldehydes in the surface water layer of Lake Strzeszyńskie in autumn was about 1/3 higher than deeper, i.e., at 2 and 4 m. This may suggest that their concentration at the lake surface depends not only on water processes but also on external factors. The influence of the surrounding environment on the lake may be realized directly through precipitation and indirectly through run-off from the catchment (Carpenter et al. 1998). Precipitation is a source of carbon, nitrogen and other elements deposited on particles of land origin, and in the vicinity of the shores also volatile organic substances of plant origin. Terrestrial plants release 400–800 Tg organic carbon (Lerdau et al. 1997) into the atmosphere during the year, which in the upper layers of the air condenses into submicroscopic particles. Some of these substances are decomposed by photochemical reactions in the atmosphere, but some return to the earth's surface with rain and snow. In this context, precipitation may be a specific and quick gateway to aquatic ecosystems of various chemical substances contained in the air. Aldehydes, low-molecular organic compounds, have been considered common in atmospheric air (Matsunaga et al. 2007, Kawamura et al. 2001). They are easily washed out of the atmosphere and, together with wet deposition, they get into surface waters. The sum of aldehydes in snow and rain is high and ranges on average from 300 μg L^{-1} to over 800 μg L^{-1}, and in the initial phase of precipitation, especially after a rain-free period, the concentration of aldehydes can be even higher and reach about 3000 μg L^{-1} (Dąbrowska and Nawrocki 2013).

Dąbrowska et al. (2014) reported that the amount of aldehydes brought with wet deposition is close to 0.3 g aldehydes per square meter per year. They made these calculations for Greater Poland Voivodeship and on the basis of the mean total content of aldehydes in rain water which is near 600 μg L^{-1}. This allows to estimate that Lake Strzeszyńskie through precipitation can receive 105 kg of aldehydes per year. However, the hitherto unspecified load of aldehydes may also come from the catchment area, which is more than 30 times larger than the surface of the lake. So far, only the loads of nitrogen and phosphorus compounds, which flow into the lake through the stream of Rów Złotnicki, the only inflow of surface water to the lake, has been assessed (Kaźmierska and Szeląg-Wasielewska 2015). Assuming that the concentration of aldehydes in this stream is 260 μg L^{-1}, as in the nearby Bogdanka river (Dabrowska and Nawrocki 2013), and the average annual flow is 0.018 m^3s^{-1} (Zawadzki et al. 2016), the load of aldehydes flowing into Lake Strzeszyńskie is about 147 kg per year. The amount of aldehydes reaching surface waters with precipitation depends on both the season of the year and sampling points located in agricultural areas and near the crossing of expressways (Czaplicka et al. 2014, Dąbrowska et al. 2014). In this context, Lake Strzeszyńskie as an urban lake located within the boundaries of a large city, is exposed to both air and traffic pollution.

Previously published results of aldehyde concentration in the surface water layer of Lake Strzeszyńskie indicated clear changes in their concentration in the annual cycle, from 55 μg L^{-1} to 435 μg L^{-1} at the average 180 μg L^{-1} (n=10) (Dąbrowska et al. 2014). Also in the water column, during these studies, both in April and December, the concentration of aldehydes varied even during full water circulation, which in Lake Strzeszyńskie usually takes place only in late autumn. The total concentration of aldehydes expressed as an average value for the water column was much higher in April than in December by almost 100%. However, both during the low and high biomass of phytoplankton the total concentration of aldehydes decreased with depth and the highest concentration was reached by formaldehyde, acetaldehyde, and propanal. Their total share in the pool of carbonyl compounds always exceeded 50%. The rapid loss of propanal in April at the depth of 4 m, not adequate to the change of phytoplankton biomass, is a cause for concern. As a result, it was not included in the group of compounds significantly correlated with phytoplankton biomass. Probably the microbiological consumption of this 3 carbon low molecular weight compound prevails at 4 m depth over its production more than at the neighboring depths. This indicates the need to extend the study to other biocenosis components. Low-molecular-weight compounds are easily biodegradable, quickly transformed enzymatically by bacteria and fungi, which often does not favor their accumulation in the environment (Leflaive and Ten-Hage 2009).

The concentrations of aldehydes in the near-surface water layer of Lake Strzeszyńskie were within the range of values found in Lake Góreckie (82–643 μg L^{-1}). The values from both months were close to the seasonal mean value of 324 μg L^{-1} (n=12) for Góreckie Lake (Dąbrowska et al. 2014). Góreckie Lake, similarly to Strzeszyńskie Lake, is of a natural origin and has a similar maximum depth, although almost 3 times larger area. It is located in the Wielkopolski National Park (Kolendowicz et al. 2007). The differences between these lakes are rather related to the proportions between the examined components of total aldehydes. It is worth noting that among the aldehydes common in the study, acetaldehyde was present in Strzeszyńskie Lake in a lower concentration than in Góreckie Lake (58.5 μg L^{-1}). On the other hand, in a slightly larger but shallow artificial reservoir Maltański, which is located in the city of Poznan, the concentration of aldehydes in the near-surface layer of water was almost two times lower – 186 μg L^{-1} (Dabrowska et al. 2014) than in Lake Strzeszyńskie. It is likely that the flowing nature and frequent water exchange did not favor the accumulation of aldehydes in this urban reservoir.

In Lake Strzeszyńskie, apart from aldehydes, the simplest ketone – acetone – was also examined. It was detected in each water sample and its average concentration in the water column was 3 times higher in April than in December, which can be associated with several times higher biomass of phytoplankton in April. Acetone was better correlated with phytoplankton biomass than the aldehydes studied, because a correlation coefficient was $r = 0.917$. Acetone is commonly found in plants, volcanic gases, forest fires, and as a product of the breakdown of body fat. The majority of the acetone released into the environment is of industrial origin. Studies by Dąbrowska et al. (2014) of the surface water layer of Lake Strzeszyńskie indicated high seasonal dynamics of acetone concentrations. In 2010, it ranged from 5.38 to 36.9 μg L^{-1} and the mean value was 19.0 μg L^{-1} (n=10). Thus, the range of acetone concentrations in the water column of the both analyzed months was smaller than the changes of acetone concentration at the lake surface during the whole vegetation season, from March to December.

The phytoplankton of Lake Strzeszyńskie in April, as expected, was dominated by diatoms and what had already been stated in this lake before (Szeląg-Wasielewska 2006). Diatoms at subsequent depths in the water column represented usually more than 50% of phytoplankton biomass followed by 17–36% of haptophytes and lower percentages of dinophytes, cryptophytes or cyanobacteria. The reason for the ecological success of diatoms is still a matter for discussion and various mechanisms explaining their prevalence in plankton were reported in the literature. According to Ribalet et al. (2014) diatoms can respond to biotic and abiotic stress such as competition, predation and unfavorable growth conditions. They produce bioactive compounds for this purpose, including polyunsaturated aldehydes (PUA). PUA have been shown to act against grazing and either increase or inhibit the growth of various phytoplankton species and bacteria both in culture and in the field. These authors found the presence of nanomolar concentrations of dissolved PUA in seawater, which suggests that these compounds are released into the water by diatoms cell lysis.

In temperate lakes, diatoms dominate in spring and sometimes in autumn, although to a lesser extent in autumn (Reynolds 2006). Among the mechanisms that give diatoms the advantage is that they have a chemical defense system that can potentially affect both predators and their food or light competitors (Ianora and Miralto, 2010, Leflaive and Ten-Hage 2009, Legrand et al. 2003, Wichard et al. 2007). Experimental studies have shown that aldehydes after crushing cells show teratogenic effects not stopping feeding but hindering the recruitment of a new generation of zooplankton. Transgenerative interactions of algae and their herbivores may occur (Wichard et al. 2007, Vidoudez et al. 2011). In Lake Strzeszyńskie in April, during the formation of thermal stratification, zooplankton could act as a stressor. As earlier studies (Budzyńska and Szeląg-Wasielewska 2006) have shown, its biomass increased successively on the sampling dates in spring.

In Lake Strzeszyńskie, the proportion of cyanobacteria in the phytoplankton biomass in both months compared was different. In December, it was slightly larger and quite similar at all studied depths, whereas in April it was visible only in hypolimnion. The biomass of cyanobacteria as a group was low, which is consistent with the seasonality of their occurrence in temperate lakes, including those used for recreation (Koreivienė et al. 2014, Szeląg-Wasielewska 2006). This suggests that a significant correlation between phytoplankton biomass and aldehydes results from the presence of other algal groups. In spring, as already mentioned above, these were diatoms and haptophytes, while in autumn – cryptophytes. The latter were recognized as supported complete ontogenesis of nauplii and copepodites of the freshwater calanoid *Eudiaptomus gracilis* (Von Elert and Stampel 2000). In turn, diatoms and hyptophytes which were co-occurring groups at all depths are both known producers of polyunsaturated aldehydes (Hansen and Eilersten 2007).

Conclusion

Due to the lability and synergistic effects of allelochemicals it is important to study these compounds in the environment. In this work, such a procedure was demonstrated to recognize the distribution of aldehydes in the water column and compare their concentrations with potential producers, i.e. phytoplankton. For comparison, a period with low and higher phytoplankton biomass was selected. The presence of significant amounts of aldehydes in lake waters was found. Particularly high concentration was identified for formaldehyde, acetaldehyde and propanal. The total concentrations of aldehydes varied widely from several dozen to several hundred micrograms per liter and in general decreased gradually with increasing depth. We have confirmed our hypothesis that the total concentration of aldehydes in lake waters is closely connected with the biomass of phytoplankton.

The next, planned stage of these studies will be the recognition of both seasonal and spatial distributions of phytoplankton and aldehydes in relation to total organic carbon. The ecological significance of aldehydes as remote--acting products of metabolism combined with their supply to waters as a result of environmental pollution exceeds the boundaries of one ecosystem. Their role clearly needs to be seen more widely and better evaluated.

Acknowledgments

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Pionowe rozmieszczenie aldehydów a struktura fitoplanktonu: studium przypadku jeziora miejskiego

Streszczenie: W systemach wodnych, zarówno biologicznie jak i chemicznie syntetyzowane cząsteczki mogą obniżać jakość środowiska i wpływać istotnie na strukturę i funkcjonowanie ekosystemów. Substancje te obejmują aldehydy pochodzące z różnych źródeł, również te związane z aktywnością producentów pierwotnych. Przedmiotem badań było rozpoznanie pionowego rozmieszczenia kilku aldehydów alifatycznych i biomasy fitoplanktonu w jeziorze miejskim w Poznaniu (Pojezierze Wielkopolskie, Polska) znajdującym się pod presją człowieka. Próbki wody pobierano od powierzchni jeziora do dna, co 2 m. Plankton analizowano pod mikroskopem odwróconym i epifluorescencyjnym. Biomasę oszacowano na podstawie pomiarów mikroskopowych i objętości komórek każdego gatunku. Trzynaście aldehydów i aceton analizowano za pomocą chromatografii gazowej z detektorem wychwytującym elektrony po procesach derywatyzacji i ekstrakcji. Stężenia aldehydów wahały się od 32,7 do 346,2 µg L^{-1}. Formaldehyd, aldehyd octowy i propanal charakteryzowały się największym stężeniem zarówno przy niskiej, jak i wysokiej biomasie fitoplanktonu. Biomasa fitoplanktonu obejmowała komórki prokariotyczne i eukariotyczne i mieściła się w przedziale od 0,25 do 2,94 mg L^{-1}. Kryptofity i okrzemki były często najważniejszymi składnikami zbiorowisk fitoplanktonu, choć w niektórych przypadkach większy udział miały haptofity i dinofity. Ogólne stężenie aldehydów było istotnie skorelowane z całkowitą biomasą fitoplanktonu ($r=0,705$, $p <0,05$), przy czym jeszcze silniejszą korelację zaobserwowano między acetonem i biomasą fitoplanktonu ($r=0,917$). Wskazuje to na fitoplankton jako ważne źródło związków karbonylowych w wodach powierzchniowych. Tym samym wiedza o różnych aspektach ich pochodzenia i rozmieszczenia w jeziorze jest ważna zarówno podczas badań ekologicznych, jak i w gospodarce wodnej.