Effect of rushes on evaporation rate in water reservoirs on the example of Powidzkie Lake

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Abstract: This paper presents research on evaporation from the lake surface within the reed bed zone. The main focus of the research was the process of evaporation of water adhered to reed culms in different weather conditions. The process of transpiration, i.e. evaporation of water from plants due to their physiological processes was ignored. To avoid any ambiguity and to stress the different nature of both processes, the studied phenomenon is referred to as „mechanical evaporation”. The analysis was based on measurements taken on Powidzkie Lake. The results showed that “mechanical evaporation” from reed culms above the water level can considerably increase evaporation rate of an aquifer. The values of total evaporation within the reed bed zone were estimated. These were compared to the values of evaporation from the open lake surface. The rate difference was at the level of 10-30%. Furthermore, the study showed that the value of “mechanical evaporation” varied depending on the reed species, wind speed and direction, wave height, and width of lakeshore with vegetation. Seasonal variations of the lake’s water surface were of slightly lesser importance.

Key words: rushes, lake surface evaporation, evaporation from culm surface, waving, transpiration

Introduction

Lake water balance is determined by two major parameters: rainfall and evaporation. For that reason evaporation from an open water surface is the subject of many studies (Jurak 1976; 1992; Jaworski 1997; Chmal 2008). Still, despite many efforts in this field, no generally accepted method for the estimate of evaporation from an open water surface exists. Researchers, therefore, face a dilemma of choosing the method that is best suited for a given reservoir. However, while all the existing equations for evaporation, e.g. Penman’s (1948), Ivanov’s (Kędziora 2008), Demianczuk’s (1967) take into account all variables related to weather conditions, they do omit other physical or biotic factors that could influence evaporation rate.

This paper proposes to demonstrate the impact these factors have on the evaporation process with examples pertaining to the influence of rushes, which are an integral part of every lake due to the fact that they often cover large parts of reservoir area. There can be no doubt that plants participate in the water cycle and affect evaporation rate and the volume of vaporized water. Plant communities that are directly

dependent on aquatic environment influence evaporation process to an even higher degree (Leśny and Juszczak 2005). There are several reasons for that. The most important one is that hydrophilic plants having unlimited access to water have not evolved “water saving” mechanisms and consequently absorb and transpire more water. Other reasons follow from the mechanical interaction of plant stems with the surrounding aquatic environment and particularly from the fact that they increase the area of evaporation surface resulting from wave breaking and capillary suction in submerged culms and leaves. And it is this last phenomenon that is discussed in this paper.

Methods

The study was carried on Powidzkie Lake located in the central part of Gnieźnieńskie Lakeland in 2008-2009. It is a large reservoir covering the area of c. 1100 ha, with a long shoreline (c. 33 km) mostly covered with high rushes and communities of willows and alder forests growing directly on the lakeshore. 50 test sites in the littoral zone were selected along the lakeshore at different distances from the average lake water range (Fig. 1).

Fig. 1. Powidzkie Lake – grey dots indicate test site locations

Each test site was a 1×1 m square (Fig. 2). Plant species were identified on the basis of analysis of selected lakeshore sections populating both shallow and steep lake bottom. Diameters of culms submerged in water and the range of water suction on external culm surface were measured (Fig. 3) and then averaged.

Width and area of littoral zone vegetation was measured in the field during lake survey and vegetation composition of reed bed zone was documented. The range of interaction between reed culms and waves was observed from land and from lake. Having gathered vegetation composition data (Table 1), numerical force of particular plant species (Table 2) and data of water suction height (Table 3), it was possible to calculate total area of exterior culm surfaces – i.e. evaporation surface. After deduction of the area taken by culms from the total littoral zone area we received the area of additional surface that evaporates water from the lake surface. It was assumed that evaporation rate from vegetation surfaces is equal to evaporation rate from open water given that constant access to water enables continuous and uninterrupted water uptake and evaporation.

The Latin equivalents of plant names correspond to “Guide to names of Vascular plants of Polish Lowlands” (Rutkowski 2006).

Fig. 2. Setting up a test site in the reed bed zone

Fig. 3. Measurement of range of water suction on external culm surface

Table 1. Species composition of particular zones [in %]

Species	Defined zones		
	A	B	C
<i>Ph. australis</i>	90	95	97
<i>T. latifolia</i> + <i>T. angustifolia</i>	4	3	2
<i>J. effusus</i> + <i>A. calamus</i> + <i>Sch. lacustris</i>	5	2	1
<i>A. glutinosa</i> + <i>S. cinerea</i> + <i>S. aurita</i>	1	—	—

Table 2. Density of plant species specimens per 1m² in defined zones

Species	Defined zones		
	A	B	C
<i>Ph. australis</i>	150	150	35
<i>T. latifolia</i> + <i>T. angustifolia</i>	20	35	25
<i>J. effusus</i> + <i>A. calamus</i> + <i>Sch. lacustris</i>	135	120	80
<i>A. glutinosa</i> + <i>S. cinerea</i> + <i>S. aurita</i>	0,5	—	—

Table 3. Suction height on culms of selected species ([in mm])

Species	Suction height
<i>Ph. australis</i>	6
<i>T. latifolia</i> + <i>T. angustifolia</i>	4
<i>J. effusus</i> + <i>A. calamus</i> + <i>Sch. lacustris</i>	4
<i>A. glutinosa</i> + <i>S. cinerea</i> + <i>S. aurita</i>	7

Results

Observation of characteristics of reed bed zone of Powidzkie Lake, such as area, width of vegetation belt, distance from shoreline, vegetation composition (Table 1), density of plants (Table 2) and wave interaction range allowed to distinguish three sub-zones. Additionally, it was noted that culm diameters of specimens of each plant species was specific to given sub-zone (Table 4). All these variables affect the total evaporation rate within reed bed zone. For purposes of this paper, the identified sub-zones will be referred to as zone A, B and C (Fig. 4).

Table 4. Culms diameters in each defined zone [in mm]

Species	Defined zone		
	A	B	C
<i>Ph. australis</i>	7	7	5
<i>T. latifolia</i> + <i>T. angustifolia</i>	25	20	19
<i>J. effusus</i> + <i>A. calamus</i> + <i>Sch. lacustris</i>	10	8	6
<i>A. glutinosa</i> + <i>S. cinerea</i> + <i>S. aurita</i>	50	—	—

Fig. 4. Reed bed zones A, B and C

The closest to shore zone A is 5-10 m wide. Here, the impact of seasonal and multiyear water fluctuations are the strongest. Due to the very small shore slope gradient, reservoir water recedes from this area during low-water periods and summer-fall season. Consequently, this zone is populated by plant species that can survive temporary inundation periods. These species include: grasses, sedges, trees and shrubs of *Alnetea glutinosae* class – forests dominated by black alder (*Alnus glutinosa*) or broadleaf willows, esp. grey willow (*Salix cinerea*) and eared willow (*Salix aurita*), and some presence of alder (*Alnus*) (Matuszkiewicz 2005). The following rushes species can be found here: narrowleaf cattail (*Typha angustifolia*) and broadleaf cattail (*Typha latifolia*), clubrush (*Schoenoplectus la-*

custris), common rush (*Juncus effusus*), and calamus (*Acorus calamus*). However, the dominant species here is common reed (*Phragmites australis*). Not only is this vegetation submerged in water periodically, but it is also unaffected by water movements caused by waves because, even during strong winds, rushes in littoral zone create a barrier which stops waves.

Located further from shoreline zone B is the widest (10-25 m) zone with the largest area of reed bed zone. This area is dominated by common reed. Other vegetation includes narrowleaf cattail, broadleaf cattail, clubrush and common rush. Zone B vegetation has the highest plant density and the largest culm diameters. Plants are significantly affected by waves – especially in the outward parts which are located closer to the open water.

Zone C occupies the smallest area and is not necessarily present along the entire shoreline. Its width oscillates between 0 m and 5 m but on the average it does not exceed 2 m. This area is inhabited in 95% by common reed with scarce presence of common rush and cattail. Some presence of yellow pond lily (*Nuphar lutea*) was also found here but, because it was minimal, it was ignored in calculations.

Observation of evaporation rate in the studied sub-zones showed that the area of evaporation surface in each zone is larger than evaporation area of open water (Table 5): in zone A by 18%, zone B – 19% and zone C – 3%. These values correspond to windless weather conditions, i.e. waveless lake.

Discussion

The results show that the presence of rushes significantly contributes to a higher evaporation rate from the lake surface. The increase occurs not only because of transpiration but is also due to the physical interaction with the surrounding water which creates conditions for evaporation of water directly from culm surface areas.

Table 5. Area of evaporation in reed bed zone at various wave height

Area [m ²]	No waves	5 cm high waves	20 cm high waves
Reed bed zone	740000	740000	740000
Area occupied by culm – no evaporation	3649	3649	3649
Open water	736351	736351	736351
Evaporation area of culm in reed bed zone	118954	158187	275887
Total evaporation area in reed bed zone	855305	894538	1012238

Consequently evaporation rate within the studied zone increases even by over 10%. This effect is intensified during windy weather when culms are flooded thus adding the number of surfaces from which water can evaporate and as a result of breaking weaves into droplets by resisting plant stems. The evaporation rate from reed bed zone in such conditions can double, and in some extreme conditions, even triple compared to windless weather.

High fluctuations of evaporation rate within the studied area depend primarily on water suction and culm diameter of each particular plant, i.e. depend of vegetation composition of reed bed zone. Another important factor is weather conditions, especially strength and direction of wind which determines wave height and is directly responsible for inundating plant stems of reed bed vegetation. The impact of waves is closely dependent on vegetation belt width and density since large density of culms reduces impact range of waves. Water level fluctuations, responsible for changes in total lake area and reed bed zone composition, also contribute to evaporation rate, although to a lesser degree.

As a result of the study, we propose to make a clear distinction between evaporation from culm surfaces and transpiration and to introduce a new term – mechanical evaporation. Mechanical evaporation would define physical participation of aquatic vegetation in the process of total evaporation from surface lake. Because of a very strong impact of this parameter on evaporation rate from water reservoirs, we propose that this phenomenon be further investigated. Such study would allow to include this variable in water balance of lakes in the future making it a more accurate and reliable representation of reality.

References

- Chmal M., 2008, Metody pomiarów parowania z wolnej powierzchni wody na Stacji Hydrologicznej w Radzynie (Methods of evaporation measurements from free water surface at meteorological station in Radzyn), *Prz. Geof.* 52(3-4): 69-78 (in Polish, English summary).
- Demiańczuk P.P., 1967, Parowanie ze swobodnej powierzchni wody w warunkach klimatycznych Polski (Evaporation from open water surface in the climatic conditions of Poland), *Pr. Stud. KIGW PAN* 8: 163-253 (in Polish, English summary).
- Jaworski J., 2004, Parowanie w cyklu hydrologicznym zlewni rzecznych (Evaporation in the hydrological cycle of river basins), *IMGW-PTGeof.*, Warszawa, p. 422 (in Polish).
- Jurak D., 1976, Intensywność parowania z powierzchni wody w zależności od charakteru zbiornika wodnego (Intensity of evaporation from water surface depending on water body features), *Pr. IMGW* 10: 5-73 (in Polish, English summary).
- Jurak D., 1992, Temperatura wody i parowanie w świetle różnych scenariuszy klimatycznych (Water temperature and evaporation after various climate scenarios), *Prz. Geof.* 37(3-4): 149-159 (in Polish, English summary).
- Kędziora A., 2008, Bilans wodny krajobrazu konińskich kopalni odkrywkowych w zmieniających się warunkach klimatycznych (Water balance of Konin strip mine landscape in changing climatic conditions), *Rocz. Glebozn.* 59(2): 104-118 (in Polish, English summary).
- Leśny J., Juszczak R., 2005, Oszacowanie ewapotranspiracji terenów znajdujących się w strefie bezpośredniego oddziaływania małych zbiorników wodnych krajobrazu rolniczego (Evaluation of evapotranspiration of areas located within the zone of direct impact of small water reservoirs in agricultural landscape), *Acta Agrophysica* 6(1): 161-174 (in Polish, English summary).
- Matuszkiewicz W., 2005, Przewodnik do oznaczania zbiorowisk roślinnych Polski (Poland's Vegetation – Plant Identification Guide), *Wyd. Nauk. PWN*, Warszawa, p. 540 (in Polish).
- Penman H.L., 1948, Natural evaporation from open water, bare soil and grass, *Proc. Roy. Soc. London* 193(1032): 120-145.
- Rutkowski L., 2006, Klucz do oznaczania roślin naczyniowych Polski niżowej (Guide to names of Vascular plants of Polish Lowlands), *Wyd. Nauk. PWN*, Warszawa (in Polish).