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Functioning conditions of small watercourse, supplying water to the recreational reservoir and opportunities to improve its quality (Janów Lubelski, south-east Poland)

Polish lowland reservoirs has a very high degree of trophy, because they are exposed to a number of threats. Currently, many artificial water suffers from eutrophication, which causes the loss of their natural and recreational values. Among them there is the reservoir in Janów Lubelski. The aim of the study was to analyze the function of natural conditions for development of recreation in the area of the reservoir. Furthermore, study of directive on ways to improve the water quality of stream supplying water into the reservoir, as well as an indication of the ability to increase its resistance to anthropogenic pressures. Condition of successful functioning of the stream and improving their ecological status was to organize the catchment, as well as propose the establishment of initial reservoir serve as a biofilter.

Keywords: **biofilter, macrophytes, water reservoir, physical and chemical features, watercourse, eutrophication**

Introduction

Poland has very low water resources amounting to about 1600 m^3 per person per year, which gives the 22 place in the European Union. The average water resources in the EU is about 4500 m^3 per person per year [1]. In addition, the parallel layout of the terrain and human activity are an important factor determining their periodic fluctuations which in turn leads to the occurrence of floods and droughts. In the basin of the Vistula River, both droughts and floods occur on average every 5 years [2]. In recent times occurrence of catastrophic events has increased, exemplified by floods in 1997 and 2010 and droughts in 2000 and 2008.

The main causes of extreme hydrological events are: variability of precipitation in time, regulation of rivers, irrational land reclamation, the lack of flood protection and protection against drought [3]. One of the basic methods of flood control is the construction of reservoirs on rivers [4]. In this respect, in Poland there are a lot of defects - only 6% of the outflow is retention, while the EU average is 15%.

Aside from retention functions, reservoirs have many others, such as fish farming, recreation, energy production [5].
Polish lowland reservoirs have a very high degree of trophy, because they are exposed to a variety of threats. When the load of pollutants flowing into the reservoir is large, the water inside is degraded. Protection from eutrophication processes is to reduce the inflow of nutrients into the reservoir. For this purpose, two methods are used in Poland. There are: arrangement of the wastewater in the catchment or initial construction of reservoirs. The best results are obtained using the complex treatments, but efforts are expensive and have a long-time implementation.
Currently, many artificial water reservoirs suffer from eutrophication, which causes the loss of their natural and recreational values. Among them there is the recreation reservoir in Janów Lubelski, where there are massive blooms of filamentous algae, and that's why there is a need to develop methods to improve the ecological status of waters.

The aim of the study was to analyze the function of natural conditions for development of recreation in the Reservoir area and to develop directions how to improve the cleanliness of its waters, as well as increase the resilience of the ecosystem to anthropogenic pressures.

1. Material and methods

Recreation reservoir in Janów Lubelski has an area of 30.1 ha (including the island 2.2 ha). It is situated on the edge of a vast forest complex "Janowskie Forests", in foothills of forested dunes, approximately 1.7 miles south from the centre of Janów Lubelski (Fig. 1).

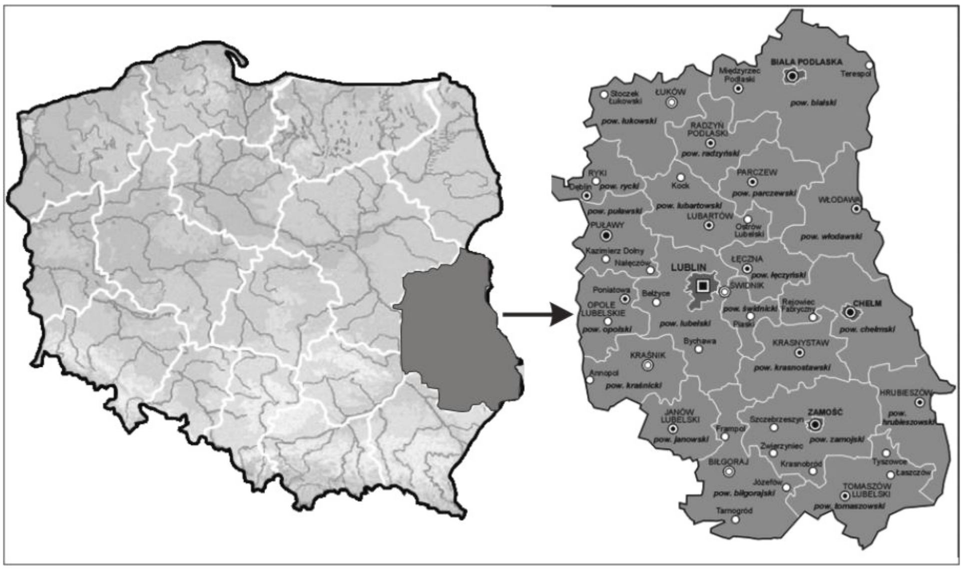

Fig. 1. Location of study area on Polish territory

The reservoir is fed tributary arising from the slope spring complex, situated in the nature reserve “Stoki Janowskie”, in the northern part of town. Because of high natural and landscape values this spring complex was considered as a natural monument. In the immediate vicinity of the headwaters a private brewery is located, as well as approximately 350 m east of the lower - the cemetery with an area of more than 6 ha, functioning for over 100 years. The spring water are used by residents of Janów Lubelski, and nearby towns.

Waters rain from the niche form create the watercourse about 1÷1.5 m wide, flowing, in the first section between single-family buildings and a meadow where the playground was located. There are wooden bridges, serve residents to wash. The initial section of a natural watercourse overgrown with aquatic vegetation. After passing the 200 m watercourse creates a small flooding overgrown with rich macrophyte communities. At 450 m distance to watercourse there is a drainage ditch connecting this watercourse with the Białka River, introducing water rich in nutrients. From this point further river bed was paved with concrete slabs, and the watercourse becomes a ditch transporting water.

After crossing the city, on the length of approximately 800 m, the watercourse flows through meadows in vicinity of single-family housing and then flows into the reservoir (Fig. 2).

The basis of the study was to determine the flow of water in the watercourse, feeding the recreational reservoir in Janów Lubelski. The study was carried out from spring to autumn in 2007. Flow measurement was performed using the direct hydraulic method at overflows (Fig. 2).

Studies of physical and chemical factors of water were conducted at four research points: 1 - outflow from the water-head, limnokren type, 2 - behind the flooding, 3 - inflow into the reservoir, 4 - reservoir (Fig. 2). Analysis of physical factors (temperature, pH, dissolved oxygen, oxygen saturation, conductivity) were carried out directly in the field, while the value of the chemical (ammonia nitrogen, nitrate nitrogen, total nitrogen, phosphates, total phosphorus, total hardness) were performed in laboratory conditions. The following instruments were used for determination of physical and chemical properties of water: OXI 330 oxymeter made by WTW (oxygen content, temperature), electronic conductivity meter made by Hanna (electrolytic conductivity), microchip Slandi SP300 pH-meter (water reaction). The content of biogenic nitrogen and phosphorus compounds was determined by using the microchip Slandi photometer LF 205.

In order to determine quality of water, 5 - point scale was used (classes: I - water with very good quality, II - water with good quality, III - water of satisfactory quality, IV - unsatisfactory quality of water, V - bad water quality). This classification is valid from 2005 (Decree of the Minister of Environment from 11 February 2004, OJ No. 32, item. 284). This is a temporary classification, because the work is continuing on the adaptation of Polish law to EU regulations.

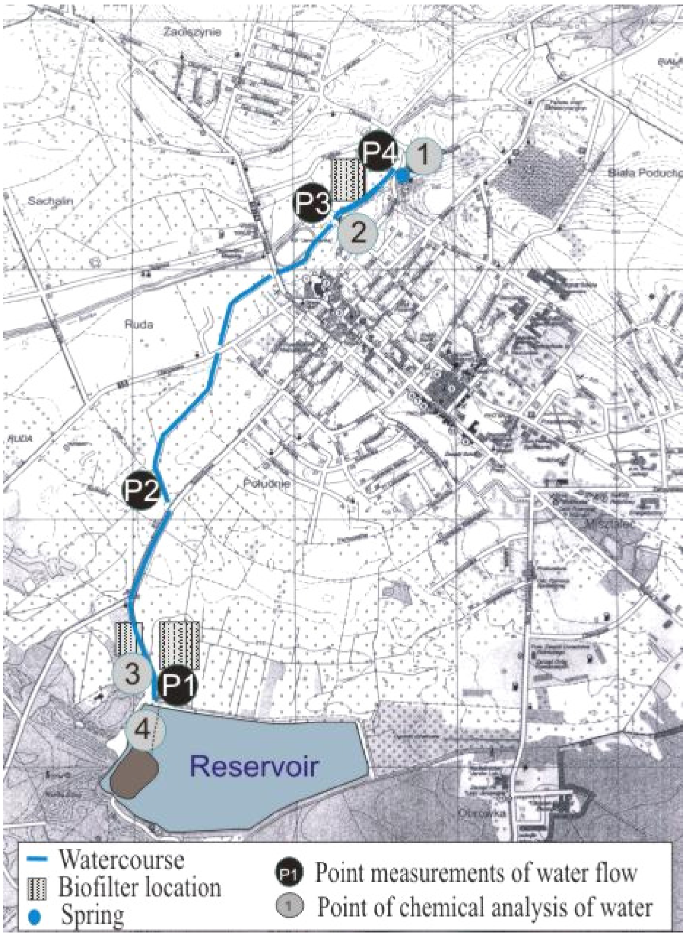

Fig. 2. Location of the watercourse, and distribution of research stations

For the watercourse and Reservoir Carlson's (1977) Trophic State Index (TSI) was calculated, based on visibility of Secchi disk (SD), nitrogen (TN) and phosphorus (TP) content.

Across the watercourse floristic analysis were also carried out. The Braun--Blanquet method [6] commonly applied in Central Europe was used.

2. Results and discussion

2.1. The volume of water flow in the watercourse feeding the reservoir

The flow of water along the watercourse was constant. Differences in the flow rate ranged up to 7 $l \cdot s^{-1}$ (Tab. 1). Such small differences between measurements are probably due to the accuracy of the measuring method and water percolation at the valve in P3.

The largest flow of water was held in October at the point located at rapids (P2). The average amount of water flow, in this hydrometric section, was 87 $l \cdot s^{-1}$ in autumn. Because of the water filtration and expansion of reservoir it is recommended to transfer the valve up the watercourse.

Table 1

The volume of water flow in the watercourse, $l \cdot s^{-1}$

Research points date	P1	P2	P3
September	90	93	87
October	78	82	75
November	82	87	81
Average	83	87	81

In analyzed period, the average amount of water flow in the watercourse was 84 $l \cdot s^{-1}$. The flow was very small and insufficient to carry out the filling of the reservoir. The filling of the reservoir should be carried out in early spring using a meltwater, which are mostly characterized by high quality and sufficient quantity.

2.2. Analysis of watercourse pollutions

The watercourse waters are characterized by an alkaline reaction. It changes in narrow range from 7.4 to 7.98 with increasing trend along the course of the river. Water reaction in the reservoir reached the value 8.33. Aerobic conditions were varied. In the upper course of the watercourse the oxygenation of the water was rather low - 85% O_2 saturation, next it was increasing up till the reservoir reached 140%.

Waters of the watercourse were strongly mineralized. An indicator of this state was conductivity, which received over 500 $\mu S \cdot cm^{-1}$. Total hardness of water was high and typical of hard waters. The values of this factor were aligned at different research points and ranged from 9.22 $mval \cdot dm^{-3}$ to 10.2 $mval \cdot dm^{-3}$ (Tab. 2).

Contents of nutrients were different. First of all, nitrate nitrogen and total phosphorus received a very high value. The watercourse waters according to physical indicators (temperature, water pH), oxygen (dissolved oxygen) and salinity (conductivity) allow to classify water qualify as the first class of quality. Nutrients suit to I (ammonia nitrogen, phosphate), III (nitrate nitrogen, total nitrogen) and V class of purity (total phosphorus).

Trophic level of the watercourse according to TSI index allows count it as hypertrophic waters (Fig. 3).

Table 2

Values of physical and chemical parameters of the watercourse water and reservoir in Janów Lubelski

Factor \ Research points	1	2	3	4
Temperature, °C $\overline{X}$	10.15	10.25	10.6	13.4
SD	0.35	1.06	2.55	3.11
Water reaction pH $\overline{X}$	7.435	7.525	8.025	8.505
SD	0.05	0.02	0.06	0.25
Dissolved oxygen, $mgO_2 \cdot dm^{-3}$ $\overline{X}$	8.61	9.53	13	15.095
SD	0.27	0.52	0.01	2.20
Oxygen saturation, % O_2 $\overline{X}$	80.75	86.1	121.2	147.2
SD	0.27	0.52	0.01	2.20
Conductivity, $\mu S \cdot cm^{-1}$ $\overline{X}$	528.5	523	521	399.75
SD	4.03	2.26	9.62	9.76
Ammonium nitrogen, $mgNH_4^+ \cdot dm^{-3}$ $\overline{X}$	0.42	0.2995	0.283	0.1605
SD	0.43	0.33	0.19	0.05
Nitrate nitrogen, $mgNO^{3-} \cdot dm^{-3}$ $\overline{X}$	17.035	17.77	15.07	13.5
SD	5.93	2.87	2.43	1.17
Total nitrogen, $mgN \cdot dm^{-3}$ $\overline{X}$	7.55	6.59	6.41	5.185
SD	0.08	0.25	0.16	0.33
Phosphates, $mgPO_4^{3-} \cdot dm^{-3}$ $\overline{X}$	0.103	0.39	0.147	0.04
SD	0.06	0.36	0.02	0.04
Total phosphorus, $mgPO_4 \cdot dm^{-3}$ $\overline{X}$	1.265	1.21	1.66	1.365
SD	0.67	0.47	0.04	0.25
Total hardness, $mval \cdot dm^{-3}$ $\overline{X}$	9.325	10.285	9.82	8.99
SD	0.15	0.12	0.27	0.30

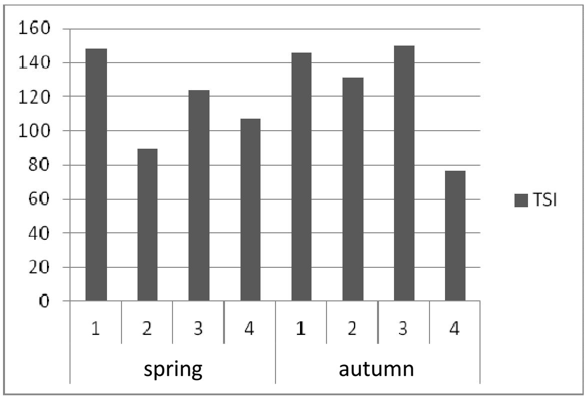

Fig. 3. Carlson Index (TSI) in research points of watercourse

2.3. The load of nutrients reaching the reservoir

To assess the magnitude of the recreational reservoir risk more important indicator than the concentration of nutrients is the load of pollutants entering to the reservoir. Along with the course, content of nutrients fluctuated. The concentration of nitrogen decreased, while concentrations of phosphorus increased. The entire length of the watercourse the ammonia nitrogen load was reduced by about 30% of nitrate nitrogen by 15% and total nitrogen by almost 17%.

Increasing of the concentration of phosphorus was significant, accounted for 30% of total phosphorus and 40% for phosphate. Concentrations of studied factors developed differently in the spring. With the exception of ammonia nitrogen (to fall by 2%) and total phosphorus (to fall by 4%). The rest values of investigated parameters were increasing with reaching of the watercourse (Tab. 3).

Table 3

The load of nutrients in the next research points of the watercourse and reservoir in Janów Lubelski

	Spring							
Research points / Factor	*average, mg · dm^{-3}				differences in absolute values between the research points mg · dm^{-3}			
	1	2	3	4	1-2	2-3	1-3	1-4
Ammonium nitrogen mgN · dm^{-3}	0.056	0.055	0.055	0.056	**↓0.001**	**0**	**↓0.001**	**0**
Nitrate nitrogen mgN · dm^{-3}	6.11	6.14	6.43	5.6	**↑0.03**	**↑0.29**	**↑0.32**	**↓0.51**
Total nitrogen mgN · dm^{-3}	7.59	8.09	9.53	12.93	**↑0.5**	**↑1.44**	**↑1.94**	**↓5.66**
Phosphates, mgP · dm^{-3}	0.118	0.2	0.203	0.052	**↑0.082**	**↑0.03**	**↑0.085**	**↓0.066**
Total phosphorus mgP · dm^{-3}	0.324	0.269	0.312	0.203	**↓0.055**	**↓0.043**	**↓0.012**	**↓0.121**

	Autumn									
Research points / Factor	average, mg · dm^{-3}				average values mg · sec^{-1}			differences in absolute values between the research points, mg · sec^{-1}		
	1	2	3	4	1	2	3	1-2	2-3	1-3
Ammonium nitrogen, mgN · dm^{-3}	0.42	0.299	0.283	0.198	34.86	26.06	23.49	**↓8.8**	**↓2.57**	**↓13.07**
Nitrate nitrogen mgN · dm^{-3}	17.035	17.77	15.07	12.67	1413.905	1545.99	1220.67	**↑132.04**	**↓325.32**	**↓193.28**
Total nitrogen mgN · dm^{-3}	7.55	6.59	6.41	4.95	626.65	573.33	519.212	**↓53.32**	**↓54.12**	**↓107.44**
Phosphates mgP · dm^{-3}	0.103	0.39	0.147	0.01	8.549	33.93	11.91	**↑25.38**	**↓22.02**	**↑3.36**
Total phosphorus mgP · dm^{-3}	1.265	1.21	1.66	1.19	104.995	105.27	134.49	**↑0.28**	**↑29.22**	**↑29.5**

* acc. to W. Wojciechowska unpubl.

On the flooding there was a clear increase of nitrate nitrogen concentration in spite of reduction this compound on the entire length of the watercourse. The phosphate concentration at the 200-meter stretch rose even 4 times. Probably a significant impact on status of water in this stretch could be a surface flow - especially after heavy rainfall and during spring melt - with the nearby built-up areas.

2.4. Floristic characteristics of the watercourse

The role of vegetation in maintaining good water quality has been known for a long time. This was confirmed by the functioning of many aquatic ecosystems [7-10]. Reservoirs so-called macrophyte type, in which a large area of the bottom covers dense submerged vegetation. Moreover, they are characterized by high water transparency, which distinguishes them from so-called planktonic type water ecosystems. Macrophytes with covering them peryphyton, compete with phytoplankton in collection of nutrients. Nutrients collected by them are built into their biomass for a long time (at least for a period of summer), in contrast to phytoplankton, which lives only from a few to several days. In the case of a higher diversity of plant communities, this process is extended in time. In temperate zone some species of buttercup and *Potamogeton pectinatus* usually die the most quicker, then *Myriophyllun sp*., and in late autumn *Polygonum amphibium* and *Potamogeton natans*, and the last *Potamogeton lucens*, sometimes in the spring of next year [11].

Macrophytes are a refuge for zooplankton and other invertebrate animals, feeding themselves filter seston out. They are a place of reproduction and development of juveniles of predatory fish, helping to increase their number. The result is a cascading effect of the impact from the top of the pyramid trophy, typical methods of water ecosystem reclamation, so-called biomanipulation.

Macrophytes forming dense carpet of plants covering the bottom, contribute to the consolidation of bottom sediments, changing the re-suspension due to mixing of water by the wind. This makes it difficult to return nutrients to the water column, even if they are large concentrations in bottom sediments. Macrophytes generate many metabolites to water, some of them are capable of inhibiting the growth of phytoplankton [12].

The vegetation of investigated watercourse was incomplete. The width of each vegetation belt was variable. The largest belts were in places, where slopes of the trough were gentle and natural.

Each succession changes of vegetation, which in lakes are induced by the living activities of plants, in river depend on the current hydrological situation, i.e. an external factor. Vegetation which overgrowing river has a clear impact on the formation of the trough and the rate of water flow, reduces water runoff, as well as prevent erosion of the bed and makes easy going down the ice.

According to overgrown degree of investigated waters, the watercourse belongs to a shallow river, with a less indented troughs and fragmentary with well-developed aquatic vegetation [13].

Section of stream from the source to the P3 is less than 300 m, but creating favorable conditions for development of aquatic vegetation (Tab. 4, 5). There was the greatest diversity of macrophyte species, both emergent and submerged among others: *Sparganio-Glycerion fluitans*, *Cicuto-Caricetum pseudocyperi*, *Phragmitetu* at this section.

Table 4

Macrophyte species occurrence in research points in investigated watercourse and reservoir in Janów Lubelski

Species \ Research points	1	2	3	4
Lysymachia nummularia L.	++			
Myostis palustris L.	+	+	+	+
Elodea canadensis L.				+++
Carex nigra Reichard.	+		+	
Urtrica dioica L.	+	++	+	
Potentilla fruticosa L.	+			
Veronica beccabunga L. (f. submersa)	++	++	+++	+
Veronica anagallis-aquatica L.	+		+	
Taraxacum officinale F. H. WIGG.	+		+	
Alopecurus aequalis SOBOL.		+	+	
Salix cinerea L.		+	+	
Solidago virgaurea L. s.s.		+		
Lysimachia vulgaris L.		+	+	
Lemna minor L.		+	+	
Lemna trisulca L.		+	+	+
Scirpus silvaticus L.		+	++	+
Phalaris arundinacea L.		+	+	+
Cirsum arvense (L.) SCOP.		+		
Callitriche cpohocarpa SENDTN.		++	++	++
Erigeron annuus (L.) PRES.		+		
Glyceria maximae (HARTM.) HOLMB.		+++	++	+
Rumex hydrolapathum HUDS.		+	+	+
Mentha aquatica L.		+		
Cicuta virosa L.		+	+	
Epilobium hirsutum L.			+	
Galium palustre L.			+	
Lycopus europeans L.			+	
Ranunculus flammula L.			+	
Phragmites australis (Cav.) Trin. ex Stedu			++	+
Tanacetun vulgare L.			+	
Ceratophyllum demersum L.			+	
Nasturtium officinale R. Br.			+	
Geranium pratense L.				+
Acorus calamus L.				+
Myosoton aquaticum (L.) Moench				+
Total	8	18	25	13

+ - occasionally, ++ - numerous, +++ - very numerous

Table 5

Morphometric characteristics and vegetation cover of the watercourse

Factor \ Research points	1	2	3	4	
Watercourse development	natural	natural	concrete	concrete	natural
Length of the section, m	87.5	200	712.5	512.5	937.5
Width of the trough, m	2.5	4	1.2	1.2	2
Area, m^2	218.75	800	855	512.5	1875
Cover, %	60	90	5	5	85
Cover, m^2	131.25	720	42.75	30.75	1155
Emergent macrophytes, m^2	91.88	216	0.75	–	998
Submerged macrophytes, m^2	39.37	504	42	30.75	157

Specific properties to development of aquatic vegetation was characterized section of river from P3 up to flowing it from Janów Lubelski city. It was section almost devoid of vegetation because a riverbank was regulated by concrete. Water area had a highly elongated shape, was relatively shallow with a very small area and volume, the coastline formed two parallel strips.

The water flowing in this ditch had a much higher speed, often shows large vertical oscillations of water. The presence in the catchment area of urbanization are connected with inflow of point sources of pollution. It can be untreated and not sufficiently treated domestic and rainy wastewater. Their load is fairly balanced throughout the year.

Good results in reducing the load pollution in watercourse is achieved by biogeochemical barriers, i.e. diervilla belt along the watercourse. Even 80% of nutrient load could be reduce in this way [14]. Possible protection of the watercourse from direct anthropogenic influences is a partial isolation of the watercourse, for example, by covering sections passing through farms.

Meadow section running from P2 until the reservoir was uneven because the length of approximately 500 m was concreted, and therefore largely devoid of vegetation, only a length of about 900 m was comfortable for vegetation because edges were smooth and natural (Tab. 5).

2.5. Analysis of the possibility of reducing nutrients flowing into the reservoir

Due to the significant content of nutrients (especially phosphorus) in spring waters and in the upper stream, it seems appropriate to device two or three small pools - areas of seepage of water through a rich vegetation zone. This zone could absorb part of the pollution. In order to increase the self-purification of the watercourse waters, pointed out three places predisposed to the location of such wetlands - biofilter [15-17].

There were two trends in investigated watercourse:
- the general trend of decreasing of ammonia nitrogen, nitrate and total nitrogen to downriver,
- fluctuations in phosphates and total phosphorus with increasing tendency.

The increase in phosphorus and nitrate nitrogen can cause the influx of pollutants with runoff and underground.

The effectiveness of nitrogen and phosphorus removing decreases out of vegetation season. In autumn and winter, as well as in spring and summer removal of contaminants is reduced by 10÷20% with the downward trend in periods of low temperatures. Much more difficult is to estimate the power of the internal watercourse of biogenic compounds. This supply is changing on an annual basis, depending on temperature [18], oxygen and iron concentration in bottom sediments, the activity of organisms inhabiting or feeding on the bottom and the water pH [19].

The maximum amount of phosphorus released from the bottom of various reservoirs range from 13.1 to 145 $mg \cdot m^{-2} \cdot d$. Thus, estimating of the size of an internal power supply is often difficult and involves a big mistake.

A role of biological filter is to increase the effectiveness of the retention of pollutants, in particular the biogenic elements - nitrogen and phosphorus. Thus, the introductory reservoir must be pre-shaped basin to ensure easy development of aquatic vegetation. Water depth should be about 0.5 to 4 m and the average flow velocity range from 0.05 to 0.3 $m \cdot s^{-1}$. In so-formed basin macrophyte should be planted. The condition for proper functioning of the filter is a right selection of plants. Typical plants serve as bio-filters should be characterize by: intensive and long-term growth (the most intense charge minerals), high production resulting in high biomass per unit area, fast-paced of collection and high possibilities of nutrients accumulation, as well as easy removal of plants from environment and natural resistance to pests [20].

Rooting vegetation acts as a substrate, microareator, heater and regulator of pollutants composition. On average, vegetation area is inhabited by about 2000 species of bacteria, several thousands of fungi. That is 100 times more microorganisms than in activated sludge. Nitrogen, phosphorus and potassium are collected by plants and stored mainly in the leaves (manna accumulates in their tissues the most of nitrogen, calamus accumulates phosphorus and potassium but it was not found in investigated watercourse). By removing the above-ground parts of plants (3÷6.5 kg $s.m. \cdot m^{-2}$), the nitrogen load can be removed about 20% and about 12% of the incoming phosphorus load.

In our climate the plant for a period of nine months of the year function as a trap of phosphorus and potassium. Outside the growing season, some of the accumulated compounds are released into the environment. However, nitrogen, which is not much active, stays firmly bound in organic debris and becoming a source of food for many species of benthic animals [21].

Ammonium is also strongly absorbed by the soil material, while a nitrate nitrogen under low oxygen is reduced to nitrogen gas with the involvement of bacterial microflora. In the case of phosphorus, adsorptions are the most important processes (complex formation with aluminum, iron and calcium), as well as temperature, pH and residence time of water. Ecosystems characterized by alkaline pH of calcium compound form stable connections with phosphorus minerals.

The greatest apply may have the following plants [22]:

– emergent - *Schoenoplectus lacustris*, *Glyceria maximae*, *Typha latifolia*, *Typha angustifolia*, *Acorus calamus*, *Phragmites australis*, collect materials mainly from the substrate,
– submerged - *Elodea canadensis*, *Ceratophyllum demersum*, *Myriophyllum spicatum*, *Potamogeton pectinatus*, a cosmopolitan species that use two sources of mineral substances - water and bottom sediments. They are fast paced of elements collection and high accumulation in their tissue (often more than emergent), but per unit area, they do not achieve a high level of accumulation due to the significantly lower production of biomass. For development they require well-oxygenated water and large transparency,
– plants with floating-leaves (pleuston) species of the family Lemnaceae; minerals derive directly from the water.

The mechanism of macrophyte filter is a biological process relay on incorporation of nutrients flowing into the reservoir into a macrophyte biomass (leaves, stems and roots). During use of the reservoir some periodic treatments, involving a formation of vegetation and sediment removal may be necessary.

The load of total nitrogen flowing in the planned reservoir, in the period after the vegetation season amounts 519.212 $mg \cdot s^{-1}$, or 44.8 $kgN \cdot d^{-1}$ and 134.5 $mg \cdot s^{-1}$ total phosphorus, in other words 11.6 $kgP \cdot d^{-1}$.

Macrophytes in full growing season are able to accumulate in their tissues [23]:

- reed - 29.6 $gN \cdot m^{-2}$ and 1.9 $gP \cdot m^{-2}$
- reed sweetgras - 56.3 $gN \cdot m^{-2}$ and 2.4 $gP \cdot m^{-2}$
- common cattail - 32.7 $gN \cdot m^{-2}$ and 3.1 $gP \cdot m^{-2}$
- sweet flag - 6.81 $gN \cdot m^{-2}$ and 2.28 $gP \cdot m^{-2}$ [21]
- great bulrush 6.27 $gN \cdot m^{-2}$ and 1.52 $gP \cdot m^{-2}$ [21]
- *Chara* species - 3.5 $gN \cdot m^{-2}$ and 0.3 $gP \cdot m^{-2}$ [24]
- common duckweed - 9 $gN \cdot m^{-2}$ and 4 $gP \cdot m^{-2}$ [9]

So that the entire load of nitrogen and phosphorus was accumulated in the tissues of macrophytes the area of wetlands should be between 800 to 1000 m^2 (Tab. 6). If the surface of the wetlands will have 800 m^2, we must assume that macrophytes are inhabited almost on the whole surface. In the wetlands with an area of 1000 m^2 macrophytes should occupy approximately 80% of its surface.

However, the efficient functioning of plant filter apart from the surface occupies by macrophytes, their biomass and density are important, but also, presence of open water surface patches. In initial time of settlement of the wetlands and their adaptation, biofilter efficiency is low and therefore results can be less than expected. In next growing seasons macrophytes increase their density and biomass, while maintaining the surface of the settlement, then results will be satisfactory.

Table 6

The accumulation of nutrients in selected macrophyte species from particular areas

Species \ Nutrient	P, kg		N, kg	
	800 m^2	1000 m^2	800 m^2	1000 m^2
Phragmites australis	1.5	1.9	23.6	29.6
Glyceria aquatica	1.92	2.4	45	56.3
Typha latifolia	2.48	3.1	26.16	32.7
Acorus calamus	1.82	2.28	5.44	6.81
Lemna minor	3.2	4	7.2	9

It is important to remember to keep as many of the species richness and diversity of macrophyte spatial structure during planting. In such wetlands, places without macrophytes play very important role as well.

Thus, given increasing of recreational use of reservoir in summer and increased nutrient loads during heavy rains, surface of this biofilter area should be 1600÷2000 m^2.

Conclusion

To achieve a successful operation of the functioning of the watercourse and improving the ecological status of the reservoir, the most important is to organize the management of its catchment area. The way of land use by the source is very important for quality of water flowing out of them.

In order to improve their quality all possibilities of formation and contaminants entering the water and soil from areas located above the headwaters niche, which before serve as industrial, residential and municipal services should be eliminated. It should also significantly increase the surface area of green spaces across the slope zones. It is recommended to use coniferous species, which prevent eutrophication of habitat. High evapo-transpiration trees should be avoid, especially poplar and chestnut trees, maples and birches. In areas of steep slopes treatments which slow down runoff, increase water retention in soil and subsoil, and protect soil from erosion should be carried out. The area should be also excluded from development of new forms of buildings, because each new area enclosed or covered with an impervious surface for the absorption of water reduces the surface for rainwater, and hence the scale of groundwater recharge, contributing to a decline in productivity of sources.

The entire route of the watercourse should be protected against pollution and abundance of water loss. For this purpose, should be enriched environment of headwaters niche of coniferous shrubs, in the bed of the watercourse to build a damming threshold height 20 cm, which will deepen the existing pools on this section and improve conditions for development of aquatic vegetation. At the same time raising of water level will protect the watercourse from the influx of the highly polluted water of Białka River, also reduce the scale of drainage from adjacent fertile meadows. In the city, where the watercourse runs in direct adjacent to buildings, a trough should be covered. An embankment of sections frequently visited by people, should be filled with trees and shrubs (fir, Canadian Hemlock, ash, elm, viburnum). On the section where the watercourse flows through meadows trees and shrubs should be planted to protect water against pollution and improve landscape aesthetics.

In the area of reservoir should be arrange a biofilter in the capacity of flooding about area of 2000 m^2 and a depth of 0.5 to 1.5 m. The pool must be surrounded by low, medium and high green zone. The water to the pool should flow into meandering streambed, similar to natural complexes. The outlet zone should be covered with reed-cane belt, at least 80 long and 10 m width.

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Warunki funkcjonowania niewielkiego cieku doprowadzającego wody do zbiornika rekreacyjnego oraz możliwości poprawy jego jakości (Janów Lubelski, południowo-wschodnia Polska)

Polskie zbiorniki nizinne cechuje bardzo wysoki stopień trofii, gdyż są one narażone na szereg zagrożeń. Obecnie wiele sztucznych zbiorników boryka się z problemem eutrofizacji, która powoduje utratę ich walorów przyrodniczych i rekreacyjnych. Wśród nich jest także zalew rekreacyjny w Janowie Lubelskim. Celem opracowania była analiza przyrodniczych uwarunkowań rozwoju funkcji rekreacyjnej w rejonie zalewu oraz przygotowanie wytycznych dotyczących sposobów poprawy stanu czystości wód cieku doprowadzającego wody do zalewu służącego do celów rekreacyjnych, a także wskazanie na możliwości zwiększenia jego odporności na oddziaływania antropogeniczne. Warunkiem prawidłowego funkcjonowania cieku doprowadzającego wody do zalewu oraz poprawy jego stanu ekologicznego było uporządkowanie zagospodarowania jego zlewni, a także propozycja utworzenia zbiornika wstępnego pełniącego rolę biofiltra.

Słowa kluczowe: **biofiltr, zbiornik retencyjny, makrofity, fizyczne i chemiczne właściwości, ciek, eutrofizacja**