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CHANGES OF FLORISTIC COMPOSITION IN THE GLOŽAN CONSTRUCTED WETLAND SYSTEM (THE VOJVODINA PROVINCE, SERBIA)

Ljiljana NIKOLIĆ, Slobodanka STOJANOVIĆ, Aleksa KNEŽEVIĆ, Dejana DŽIGURSKI, Branka LJEVNAIĆ

University of Novi Sad, Faculty of Agriculture, Novi Sad, SERBIA

Abstract
The constructed wetland system for municipal wastewater treatment in Gložan (near Novi Sad) is the first facility of its kind in Serbia. This biological purification system, whose final recipient in the Danube River, covers an area of 1 ha. Biomonitoring was conducted in the period 2004-2008 to assess the changes and dynamics of the floristic structure at the examined site. In the first year (2004), 41 vascular flora taxa were recorded. The respective figures in 2005, 2006, 2007 and 2008 were 34, 33, 21 and 25 taxa. Considering the total period (2004-2008), we recorded a total of 53 taxa of which 14 occurred in all study years. The paper presents also the changes in the biological spectrum and range of habitat types registered over the five-year period. In addition to its main function within the process of biological purification of municipal wastewaters, the constructed wetland system also plays an important role in the framework of sustainable development, since environmental protection is one of its major components.

1. INTRODUCTION

The first constructed wetland system (CWS) for municipal wastewater treatment prior to discharge into a watercourse was built in England in late 1970s and early 1980s [11]. Nowadays, this method is used worldwide but it is not universally accepted everywhere. In our country, the method was used for the first time in 2004. The EU Directive 91/271/EEC (1991), which deals with municipal wastewater treatment, strongly recommends constructed wetland systems. Within the framework of a pilot project titled „Municipal wastewater treatment by the method of constructed wetlands", the first biological purification system in Serbia, with the Danube River as the final recipient, was constructed in the village of Gložan, near Novi Sad. The Gložan constructed wetland system was built on a site of a natural swamp, its area is 1 ha and it comprises three separately constructed cells.

This method is based on the utilization of phytofiltration and phyto-accumulation capacities of semiaquatic plants (macrophytes) which take up, retain and accumulate different substances from soil and water [1,2,8,9,13,6,10]. Furthermore, owing to well-developed rhizomes and root system, these plants provide in their rhizosphere a viable environment for microorganisms, which, together with plants, play an important role in the processes of decomposition of debris in water and its underlying soil substrate.

While conventional methods of wastewater purification are time- and energy-consuming as well as expensive, wetlands are a natural water filter that grow and purify the environment, acting as super-absorbers of phosphates, nitrates and various hazardous substances. CWSs are an example of clean technology that exploits solar energy and provides useful biomass as final product.

Monitoring of floristic structure, biological spectrum and chorological spectrum, are integral parts of permanent biological and ecological studies, which were the objectives of this paper. The obtained data may serve as indicators of course of succession of the studied anthropogenic wetland ecosystem.

2. MATERIAL AND METHODS

The floristic study in the Gložan CWS covers a five-year period (2004-2008). Plant species were determined in accordance with the publications Flora SR Srbije [7], Visügyi hidrobiologia [3] and Flora Europaea [15]. Presence of life forms was estimated on the basis of A magyar flóra és vegetáció rendszeretani novényfoldrajzi kézikonyve [12], floristic elements on the basis of Pregled vrsta flore SR Srbije sa biljnogeografskim oznakama [4].

Table 1. Flora review of the Gložan constructed wetland system (2004-2008)

Floristic element	Life form	Plant species	2004	2005	2006	2007	2008
Adv.	Th	*Abutilon theophrastii* Medik.	+	+	+	+	+
Adv.	Th	*Amaranthus retroflexus* L.	+		+		
Adv.	Th	*Ambrosia artemisiifolia* L.	+	+			
Sub-M.	H (G)	*Aristolochia clematitis* L.	+				
Adv.	G(H)	*Armoracia lapathifolia* Gilib.	+				
Adv.	H	*Aster salignus* Willd.	+	+	+	+	+
Cosm.	HH-G	*Bolboschoenus maritimus* (L.) Palla.			+		
Eur.	H	*Calystegia sepium* (L.) R. Br.		+	+	+	+
Sub-CE	TH	*Carduus acanthoides* L.		+	+		
Cosm.	Th	*Chenopodium album* L.	+		+	+	+
Sub-Eur.	Th-H	*Conium maculatum* L.					+
Cosm.	H-G	*Convolvulus arvensis* L.	+		+		
Sub-Eur.	G	*Cirsium arvense* (L.) Scop.	+	+	+		
Cosm.	Th(H)	*Datura stramonium* L.	+				+
Sub-Eur.	Th-H-H	*Daucus carota* L.		+			
Adv.	Th	*Echinocystis lobata* (Michx.) Torr.et Gray.	+	+	+	+	+
Sub-Eur.	H-HH	*Epilobium hirsutum* L.		+	+		+
Adv.	Th-TH	*Erigeron canadensis* L.	+	+	+	+	
Sub-CE	H	*Eupatorium cannabinum* L.	+	+	+	+	+
Sub-CE	Th	*Galinsoga parviflora* Cav.	+		+		
Sub-M.	M	*Galega officinalis* L.	+	+			
Eur.	H(Ch-G)	*Glechoma hederacea* L.		+			
Sub-M.	TH-Th	*Helminthia echioides* (L.) Gärtn.	+				
Sub-CE	TH-H	*Innula britanica* L.	+	+	+		+
Subpont. subca.subm	Th-TH	*Lactuca serriola* L.	+		+		
Eur.	Th-TH	*Leonurus marrubiastrum* L.	+				
Sub-Eur.	HH	*Lycopus europaeus* L.	+	+	+	+	+
Sub-CE	Ch	*Lysimachia numularia* L.		+			
Eur.	HH	*Lysimachia vulgaris* L.		+			
Eur.	H-HH	*Mentha aquatica* L.					+
Circ.	H(G)	*Mentha arvensis* L.	+		+	+	
Adv.	Th	*Panicum capillare* L.	+	+	+	+	+
Cosm.	Th	*Panicum crus-galli* (L.) P.B.	+	+	+	+	+
Sub-M.	H	*Parietaria officinalis* Mert. et Koch	+				
Cosm.	HH	*Phragmites communis* Trin.	+	+	+	+	+
Sub-circ.	Th	*Polygonum lapathifolium* L.	+	+	+	+	+
Cosm.	Th	*Polygonum aviculare* L.	+				
Sub-Eur.	Th	*Pulicaria vulgaris* Gaert.	+		+		
Subjsib.	H-N	*Rubus caesius* L.	+	+			+
Sub-CE	H-HH	*Rumex hydrolapathum* Huds.	+	+			
Sub-Eur.	Th	*Setaria viridis* (L.) P.B.	+	+	+		
Sub-Eur.	Th	*Sinapis arvensis* L.	+				
Sub-Eur.	Ch	*Solanum dulcamara* L.		+	+	+	
Cosm.	Th	*Solanum nigrum* L.				+	+
Adv.	H	*Solidago serotina* Aiton.	+	+	+	+	+
Eur.	H	*Sonchus arvensis* L.	+	+	+	+	+
Circ.	H	*Stachys palustris* L.	+	+	+		+
Cosm.	Th-TH	*Stellaria media* L.	+	+	+		
Adv.	Th	*Stenactis annua* (L.) Nees.	+	+			
Sub-CE	H	*Symphytum officinale* L.	+	+	+	+	+
Eur.	H	*Urtica dioica* L.	+	+	+	+	+
Adv.	Th	*Xantium strumarium* L.	+	+	+	+	+
Adv.	Th.	*Xantium italicum* Mor.	+	+	+	+	+
Total number of species			**41**	**34**	**33**	**21**	**25**

Legend: Adv. – Adventive**, Sub-M. –** Sub-Mediterranean, **Cosm. –** Cosmopolitan, **Eur. –** Eurasian, **Sub-CE -** Sub-Central European, **Sub-Eur. –** Sub-Eurasian**, Sub-Pont. sub-CA - sub-M. -** Sub-Pontic-Sub-Central Asian - sub-Mediterranean**, Circ. –** Circumpolar**, Sub-circ. –** Sub-circumpolar**, Subjsib**. - Sub-South Siberian; **Th** – Therophyte, **H** – Hemicryptophyte, **HH** - Hydato–helophyte, **M** - Microphanerophyte, **G** - Geophyte, **TH** – Hemitherophyte, **Ch** - Chamaephyte

3. RESULTS AND DISCUSSION

Study results include an analysis extant flora, percent presence of plant life forms and their floristic elements in the Gložan CWS. Within the framework of continual floristic studies conducted in the period 2004-2008, a total of 53 taxa were recorded, of which 14 taxa were common in all study years (Table 1). The highest floristic richness, that included 41 taxa of vascular flora, was registered in the first year (2004). The respective figures in the subsequent years, 2005, 2006, 2007 and 2008, were 34, 33, 21 and 25 taxa.

The richness of the recorded flora results from a number of factors, but primarily from favorable hydrological conditions in the Gložan CWS, which had been constructed at the site of a natural swamp. Additionally, the continual inflow of municipal wastewater resulted in profuse growth of reed (*Phragmites communis* Trin.) stands. At first, the reeds had thrived naturally and later on they were additionally planted. The reeds achieve their maximum growth and the height of about 4 m in the first cell of the CWS, which has highest moisture content in the underlying substrate. Because of very favorable ecological conditions (moisture, temperature, light, presence of nutrients in wastewater), the reeds formed a thick stand which suppressed the other species in the cell itself and pushed them to the very perimeter of this part of the system.

It seems important to mention at this point that, in spite of a relative floristic richness which was characteristic only for the perimeter of the first cell of the system, the reed was absolutely predominant in all three cells of the system and across the entire five-year period, being the main factor of phytofiltration and phyto-accumulation of a variety of substances from the wastewater coming from the village of Gložan. Only around the weirs between the system's cells, where the reeds were thinner and the light regime was better, did a hemicryptophyte *Calystegia sepium* (L.) R. Br. manage to thrive, climbing up the reed stalks and causing their partial lodging.

The analysis of the biological spectrum of recorded species indicated that therophytes (Th) predominated in all study years. Their numbers and percentages in 2004, 2005, 2006, 2007 and 2008 were 21 species (51.22%), 13 species (38.23%), 15 species (45.45%), 10 species (47.62%) and 11 species (44%), respectively. Presence of hemicryptophytes (H) was also significant. Their respective numbers and percentages were 13 species (31.71%), 12 species (35.29%), 11 species (33.33%), 8 species (38.09%) and 11 species (44%). Hydro-helophytes were present in low numbers, but here it should be mentioned that the predominant species in the Gložan CWS was the reed, a hydro-helophyte perfectly adapted to the conditions in the studied anthropogenic ecosystem. Hemitherophytes, chamaephytes, geophytes and microphanerophytes were also present in low numbers. The last two life forms were not recorded in the last two years of the study at all (Table 2).

Table 2. Review of life forms in the Gložan constructed wetland system (2004-2008)

GROUP OF LIFE FORM	LIFE FORM	SPECIES NUMBER AND PERCENTAGE				
		2004	2005	2006	2007	2008
Therophyte Th	Th Th (H) Th –TH Th -TH-H	16 (39.02%) 1 (2.44%) 4 (9.76%)	10 (29.41%) 2 (5.88%) 1 (2.94%)	12 (36.36%) 3 (9.09%)	9 (42.86%) 1 (4.76%)	9 (36.00%) 1 (4.00%) 1 (4.00%)
Hemicryptophyte H	H H-HH H (G) H-G H-N H (Ch - G)	8 (19.51%) 1 (2.44%) 2 (4.88%) 1 (2.44%) 1 (2.44%)	8 (23.53%) 2 (5.88%) 1 (2.94%) 1 (2.94%)	8 (24.24%) 1 (3.03%) 1 (3.03%) 1 (3.03%)	7 (33.33%) 1 (4.76%)	8 (32.00%) 2 (8.00%) 1 (4.00%)
Hydato–helophyte HH	HH HH-H HH-G	2 (4.88%)	3 (8.82%)	2 (6.06%) 1 (3.03%)	2 (9.52%)	2 (8.00%)
Microphanerophyte M	M	1 (2.44%)	1 (2.94%)			
Geophyte G	G G (H)	1 (2.44%) 1 (2.44%)	1 (2.94%)	1 (3.03%)		
Hemitherophyte TH	TH TH-H TH-Th	 1 (2.44%) 1 (2.44%)	1 (2.94%) 1 (2.94%)	1 (3.03%) 1 (3.03%)		 1 (4.00%)
Chamaephyte Ch	Ch		2 (5.88%)	1 (3.03%)	1 (4.76%)	

The analysis of the chorological spectrum indicated a predominance of species of wide distribution: **adventive** – 12 (29.27%) in 2004, 10 (29.41%) in 2005, 9 (27.27%) in 2006, 8 (38.09%) in 2007 and 7 (28%) in 2008; **Eurasian** – 9 (21.95%) in 2004, 12 (35.3%) in 2005, 9 (27.27%) in 2006, 5 (23.81%) in 2007 and 8 (42%) in 2008; **circumpolar and cosmopolitan** - 10 (24.39%) in 2004, 5 (14.7%) in 2005, 9 (27.27%) in 2006, 6 (28.57%) in 2007 and 7 (28%) in 2008. The species of wide distribution comprised over 75% of the spectrum in all study years (75.61% in 2004; 79.41% in 2005; 81.81% in 2006; 90.47% in 2007 and 88% in 2008), which is in agreement with the ecological conditions prevailing in this anthropogenic ecosystem.

The presence of species of narrow distribution (sub-Central European, Pontic-Central Asian and sub-Mediterranean) was low. The presence of Pontic-Central Asian and sub-Mediterranean species in the first three years was an indication of an intensive water release during the summer period in initial years of operation of the system (Table 3).

Table 3. Review of chorological spectrum in the Gložan constructed wetland system (2004-2008)

CHOROLOGICAL TYPE	FLORAL ELEMENT	NUMBER OF SPECIES AND CORRESPONDING PERCENTAGES				
		2004	2005	2006	2007	2008
Adventive	Adventive	**12** (29.27%)	**10** (29.41%)	**9** (27.27%)	**8** (38.09%)	**7** (28%)
Eurasian	Eur. Sub-Eur. Sub-s. Sib.	**3** (7.32%) **5** (12.19%) **1** (2.44%)	**5** (14.71%) **6** (17.65%) **1** (2.94%)	**3** (9.09%) **6** (18.18%)	**3** (14.29%) **2** (9.52%)	**4** (16%) **3** (12%) **1** (4%)
Circumpolar and cosmopolitan	Cosm. Circ. Sub-circ.	**7** (17.07%) **2** (4.88%) **1** (2.44%)	**3** (8.82%) **1** (2.94%) **1** (2.94%)	**6** (18.18%) **2** (6.06%) **1** (3.03%)	**4** (19.05%) **1** (4.76%) **1** (4.76%)	**5** (20%) **1** (4%) **1** (4%)
Central European	Sub-CE	**5** (12.19%)	**6** (17.65%)	**5** (15.15%)	**2** (9.52%)	**3** (12%)
Pontic-Central-Asian	Sub-Pont.-sub-CA.sub-M.	**1** (2.44%)		**1** (3.03%)		
Sub-Mediterranean	Sub-M.	**4** (9.76%)	**1** (2.94%)			

The plant cover formed in the Gložan CWS comprises 13 adventive plant species. Among these, invasive plant species (*Abutilon theophrasti, Ambrosia artemisiifolia, Erigeron canadensis, Xantium italicum, Xanthium strumarium*) are of particular concern because of their negative impact on the native flora. Their aggressive expansion tends to degrade the ecological balance [16, 14]. The presence of invasive plant species in systems for purification of communal wastewater calls for their permanent monitoring because these plants may negatively affect the biodiversity of a given site, while a CWS may in itself become a focal point for further spread of these plants [14].

The analyses of floristic composition, biological spectrum and chorological spectrum made over the five-year study period indicated a succession towards a swamp ecosystem predominated by *Phragmites communis,* a cosmopolitan hydro-helophyte which plays a key role in the purification of communal wastewater in the Gložan CWS. The above data show that the reed adapted perfectly to the ecological conditions of the studied site and, due to high competitiveness and allelopathic action [5], it suppressed the other plant species, as indicated by a steady reduction in the number of plant species across the study years.

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