Pergamon

Wat. Sci. Tech. Vol. 33, No. 4-5, pp. 303–308, 1996.

0273–1223/96 $15·00 + 0·00

PII: S0273-1223(96)00245-4

CONSTRUCTED WETLANDS IN THE CZECH REPUBLIC – SURVEY OF THE RESEARCH AND PRACTICAL USE

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ABSTRACT

In the Czech Republic numerous constructed wetlands were designed and built for point and non-point pollution abatement in recent years. The contribution brings a concise survey of the progress made in the research and practical application of these systems. Appx. 39 constructed wetlands were in operation or under construction in 1995. Their treatment effect and function have been monitored and evaluated. The greatest constraint is a lack of practical experience. To prevent unnecessary mistakes it is desirable to use the experience from countries whith a longer tradition in construction and operation of such systems. Nevertheless, the research results, which have been obtained in the Czech Republic could be also useful for designers in other countries. Copyright © 1996 IAWQ. Published by Elsevier Science Ltd.

KEYWORDS

Constructed wetlands; emergent aquatic plants; floating aquatic plants; point and non-point pollution; water quality.

INTRODUCTION

Constructed wetlands are becoming increasingly popular for wastewater treatment around the world. They have been used to treat a wide variety of wastewaters including domestic (ranging from individual home to municipal systems), industrial, mine drainage, landfill leachate and urban stormwater (Brown, 1994).

Exchange of information among the Czech specialists dealing with the use of aquatic and wetland plants for water pollution control was made possible by establishing the national contact group "Use of Green Plants for Water Quality Improvement" in Brno in 1986. The group organized meetings and issued three subject reports summarizing the state of knowledge and investigations, including reviews of international scientific activities (Žáková *et al.* 1987, Žáková 1990, 1991). The group stopped formal meetings in 1989, but its members have been helping in the practical application of these systems in the Czech Republic.

Constructed wetlands can be classified according to the life form of the dominating macrophyte in the wetland into (i) free floating macrophyte-based systems, (ii) emergent macrophyte-based systems, and (iii) submerged macrophyte-based systems (Brix, 1993).

FREE FLOATING MACROPHYTE-BASED SYSTEMS

Research

Many experiments were performed to study the possibility of the practical application of facilities with floating water plants for wastewater treatment under climatic conditions prevailing in the Czech Republic. Water hyacinth (*Eichhornia crassipes*) and duckweed (*Lemna* sp.) systems for wastewater treatment and nutrient removal were tested in some localities in South Bohemia, North and South Moravia (Kvet *et al.*, 1982, Lecianová, 1984, Žáková, 1984, 1991, Žáková and Véber, 1991, Žáková *et al.*, 1994, etc.).

In South Moravia experiments were performed in some natural reservoirs and also in four water treatment plants (Žáková, 1991, Žáková and Véber, 1991). Growth characteristics of water hyacinths were investigated during the period 1982 to 1991. Under natural conditions in NovÇ Ml ny Reservoir, South Moravia, the average daily production for the period July–October (73 days) was 7.9 g m^{-2} d^{-1} dry matter (yearly production 127 t ha^{-1}), in the Odrovice Impoundment the average daily dry matter production (June–July, 42 days) was 8.9 g m^{-2} d^{-1}. The water hyacinths grew well in biologically treated waste waters from municipal water treatment plants of Brno, Kuøim, Hodonín and Uherské Hradi tì. The average daily production in the effluent from the city of Brno waste water treatment plant was 14.7 g m^{-2} d^{-1} (July–September 1985, 56 days, without harvesting) and 17.6 g m^{-2} d^{-1} (July–October 1988, 109 days, with harvesting: July–August weekly, September–October bi-weekly). Maximum net daily production – 29.5 g m^{-2} d^{-1} dry weight occured during August 1986 (Žáková, 1988).

The duration of growing season amounted to 100 days in natural localities, and to more than 120 days in moderately heated biologically treated waters (depending on actual conditions). During winter the adequate inoculum of plants was transferred to greenhouse (approximate optimum temperature 10–18°C, light intensity more than 18 W m^{-2} PhAR).

Nutrients were very quickly consumed by the water hyacinth in stagnant water conditions. Water quality was improved by up to three quality classes (according to CSN 75 7221). Using shallow experimental basins with horizontal flow and retention time ranging between 17 hrs to 6 days, it was possible to remove from the secondary effluent ammonia-N completely, nitrate-N up to 95%, total phosphorus by 94%, dissolved phosphorus by 80%, potassium by 94%, non-dissolved matter by 97%, BOD5 by 93%, COD by 87%, and to increase the DO-concentration by 185%.

These experiments showed that for an efficient water treatment it was necessary to harvest biomass regularly and remove the sludge sediment. The water hyacinth removed also heavy metals and other contaminants (pesticides, PCB). These contaminants were partly accumulated within the biomass, partly in sludges on the bottom of experimental basins. Experimental feeding of biomass to rams, rabbits, geese and nutria (*Myocastor coypus*) did not impair the health of the animals (Vesel, cited in Žáková, 1991).

The results of these experiments also showed also that the maximum rate of dry matter production and water treatment capacity during the summer period attained values which were comparable to those attained in tropical and subtropical zones. However, the vegetative period under natural conditions of South Moravia (and probably of the lowlands of the
whole of the Central Europe) was approximately half the time of tropical and subtropical zones and resulting in lower total yields.

The main topics of experiments performed in 1991 were:

- to assess the temperature dependence of growth and reproduction of Eichhornia crassipes in conditions prevailing in South Moravia, and,
- to test the possibility of extending the growing season.

A strong temperature limitation of the growth of water hyacinth was found. The intense growth of Eichhornia was observed after the average daily temperature had reached 18°C. It was possible to prolong the vegetative period of water hyacinth, and treatment of the effluent, by covering experimental basins with a polyethylene shelter.

Experiments with water hyacinth proved that the use of such systems is realistic, but only for specific applications (for
example for heated wastewaters containing high concentrations of nutrients or for sewage from small seasonal summer
residences).

Practical use

The use of these systems in the Czech Republic is still in the experimental stage.

EMERGENT MACROPHYTE-BASED SYSTEMS

Research

The aim of research and education in the Czech Republic is to improve the level of understanding and to suggest tasks that have to be tackled in order to make constructed wetlands a reliable wastewater treatment option. Due to inadequate information of decision makers, engineers and potential users, the constructed wetlands face controversial attitudes – either uncritical recommendation or equaly uncritical rejection (Círková-Koncalová and Husák, 1992).

The main task of the Institute of Botany of the Czech Academy of Sciences in Trebon, was to evaluate the role of plants in constructed wetlands using local data as well as those obtained on constructed reed beds in West European countries; data on the rates of evapotranspiration were delt with by (Pribán 1992), on nutrient uptake by Dykyjová (1992) and on oxygen transport to the rhizosphere by Círková-Koncalová (1992a). The second task was to identify tolerance limits for various wetland plant species with respect to the following characteristics: 1) grain size (soil, sand, gravel) of substrate, 2) degree (duration) of anoxia in the rhizosphere (including interaction with substrate type and nutrient loads), 3) timing and frequency of cutting, 4) climatic factors (high altitudes), 5) shading (Círková-Koncalová, 1992b).

Considering these factors a list of plant species suitable for constructed wetlands has been prepared (Husák, 1992). The Institute of Botany in Tøeboò started advising on biological aspects of constructed wetlands as a complement to the commonly elaborated engineering aspects.

The respective biological projects include recommendations on:

- species composition,
- propagation and planting method,
- maintenance of vegetative cover after its establishment.

The experimental work in the Department of Landscape Water Management of the Technical University in Brno is focused on the studying of the purification effect of reed bed treatment systems with horizontal and vertical flows. This research gives consequently new impulses to the design of reed bed treatment units taking into consideration gradual loading, impulse filling and emptying of the filtration bed, etc. (Šálek, 1994; Marcián and Šálek, 1994).

Table 1. Survey of the Czech constructed wetlands (according to Vymazal, 1995)

Locality	Wetland Surface Area (m^2)	Population Equivalent	Purpose *
Kořenec	6 000	450	M + R
Koloděje	4 493	900	M
Zásada	4 384	1100	M
Osová Bitýška	3 880	1000	M + R
Spálené Poříčí	2 500	700	M + R
Trutnov	2 416	380	M
Olší	2 160	267	M
Lipka	2 200	300	M
Onšov	2 100	551	M
Němčičky	1 850	640	M + R
Drahlín	1 728	600	M
Biskoupky	1 458	240	M
Petrov	1 104	333	M
Čičenice	1 020	335	M + O (brickw.)
Ondřejov	806	362	M
Krucenburk	750	150	M
Chmelná	706	150	M + R
Kačice	600	43	O (dairy), F
Benešov	600	80	M
Hrochův Týnec	572	-	R
Lišný	550	190	M + R
Žernovník	545	175	M
Příchovice	500	667	M, F
Doksy	300	75	M
Veselý Žďár	288	70	M
Michalovice	250	150	M + R
Kořenov	216	55	M
Verneřice	200	40	M
Velešice	200	40	M
Chřibská	200	150	M, F
Koberovy	180	24	M
Chotouň	100	10	M
Dolní Černá Studnice	96	15	M
Liboc	80	20	M
Dvůr Králové	40	8	M
Trnovany	32	7	O (bakery) , F
Únětice	26	10	M
Žitenice	18	4	M

* M - municipal wastewater treatment, R - rainwater, O - other wastewater, F - final treatment

Practical use

Appx. 39 constructed wetlands were in operation or under construction in 1995. The first constructed wetland in the Czech Republic has been in operation since 1989 in Petrov near Jílové. Vymazal (1995) presented a list of the Czech constructed wetlands (in use or in construction) – see Table 1.

Most of wastewater treatment facilities listed above are gravel beds planted with reed (*Phragmites australis*) and are designed to work as systems with a subsurface continuous horizontal flow of wastewater. The surface area per inhabitant (pe) is in 54% plants from 3.6–5.0 m^2, in 27% 2.0–3.5 m^2 and in 19% of systems is the area more than 5 m^2 per inhabitant (pe). Most of these systems have a mechanical pretreatment (screen, settling tank, grit chamber). Construction costs varied widely (in most cases from 2000- to 6000 Kç per inhabitant - pe). Annual operating costs are very low.

Table 2. Effluent quality from some monitored Czech constructed wetlands according to Hrncír and Vácha (1994).

Locality	Effluent BOD conc. $mg.l^{-1}$	Average flow $m^3.d^{-1}$	Treatment efficiency %	Starting date
Valešice	7.7	2.6	95.0	1 993
Chmelná	3.0	111.8	87.5	1 992
Trnovany	60.0	3.5	80.0	1 992
Žitenice	24.7	0.5	87.6	1 993
Michalovice	9.2	22.5	92.3	1 994

RESULTS AND DISCUSSION

Research and practical use of constructed wetlands and aquatic plant treatment systems do not have a long tradition in the Czech Republic. The greatest constraint is a lack of practical experience. To prevent unnecessary mistakes it is desirable to use the experience from countries whith a longer tradition in construction and operation of such systems.

Nevertheless, the research results, which have been obtained in the Czech Republic could be also useful for designers in other countries. They pertain to the following topics:

- determination of the conditions and limitations for waste water treatment using water hyacinth and some other floating plants in Central Europe,
- data on the rates of evapotranspiration, nutrient uptake, oxygen transport to the rhizosphere etc. in the emergent macrophyte-based systems,
- identifying of the tolerance limits for various wetland plant species with respect to the following factors:
    - grain size – substrate texture (soil, sand, gravel),
    - degree (duration) of anoxia in the rhizosphere (including interaction with substrate type and nutrient loads),
    - timing and frequency of cutting,
    - climatic factors (high altitudes),
    - shading,
    - choice of plant species suitable for constructed wetlands in Europe,
    - advising on biological aspects of constructed wetlands as a complement to the common engineering projects.

The biological aspects include:

- species composition,
- recommended propagation and planting method,
- maintenance of the established vegetative cover,

- research results on new construction and arrangment of reed bed treatment units taking into consideration their gradual loading, impulse filling and emptying, etc.

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