Environment Protection Engineering

Vol. 19 1993 No. 1–4

DANUTA LESZCZYŃSKA*, ANDREW A. DZURIK**

SIMULTANEOUS TREATMENT OF WASTEWATER AND STORMWATER RUNOFF USING CONSTRUCTED WETLANDS

Constructed wetlands are becoming increasingly important as a technology of water treatment. Considerable interest in these systems is caused by new federal regulations concerning stormwater discharge and implementation of requirements for water quality. Application of constructed wetlands in storage and treatment of stormwater is a promising alternative for wastewater treatment facilities. The decision on the construction of such a system depends on numerous characteristics, e.g. climate, waste load, existing land use and budget.

In the paper, the review of the constructed wetlands operating in the U.S.A. is presented. They are divided into two major categories: free water surface (FWS) and subsurface flow (SF) wetlands. The information presented in the paper is based on literature, computer programs, federal agencies and personal discussions with scientists. Under optimal conditions such wetlands can be useful in solving the wastewater treatment problems in small communities with low budgets.

1. INTRODUCTION

The last decade, especially the last 5 years, has brought an increasing number of the constructed wetland (CW) systems into operation. Those systems are promising alternatives for some of the costly wastewater treatment facilities that are traditionally used for wastewater treatment. They are also an inexpensive option of water polishing. Depending on the need, CWs can be used for storage and treatment of different types of wastewater: from municipal wastewater to acid mine drainage, industrial process water, agricultural non-point discharges, stormwater treatment

---

*Department of Chemistry, Jackson State University, Jackson, MS 39217-0510, USA.

**Department of Civil Engineering, Florida A&M University/Florida State University, Tallahassee, FL. 32316-2175, USA.

and for simple storage of stormwater. According to REED and BROWN [13], U.S. EPA documents have shown more than 150 constructed wetlands in the United States in use at the end of 1990. Carefully designed, CWs can especially be useful for small communities, usually struggling with limited resources. Under optimal conditions they can be used for simultaneous treatment of municipal wastewater and stormwater runoff.

2. CLASSIFICATION OF CONSTRUCTED WETLANDS

Constructed wetlands are defined as a designed and man-made complex of saturated substrates, emergent and submerged vegetation, animal life and water that simulates natural wetlands for human use and benefits. These man-made wetlands are designed specifically for use in treatment of wastewater, and the character of the wetlands can be designed to fit the need presented by particular wastewater.

Wetlands consist of five main components (HAMMER [6]):

1. Substrates with various rates of hydraulic conductivity.
2. Plants adapted to water-saturated anaerobic substrates.
3. A water column (water flowing in or above substrate's surface).
4. Invertebrates and vertebrates.
5. Aerobic and anaerobic microbial populations.

These major components are adjusted either to give a different orientation or favour a type of treatment of wastewater.

Constructed wetlands can be divided into two major categories: (1) free water surface (FWS) and (2) subsurface flow (SF) wetlands.

The FWS wetlands are designed to imitate natural wetlands, mostly marshes. They usually have soiled bottoms, emergent vegetation and water exposed to the atmosphere. The vegetation is planted in the shallow basins or channels with relatively low water depth. The type of soil ranges from gravel to clay or peat. The decision about the specific type of the soil used for construction should consider: (1) application of the system (e.g., wastewater treatment, or water polishing), (2) types of expected pollutants and their concentrations (e.g., metals, phosphorus compounds, expected pH), (3) type of vegetation. The whole system can be designed as non-discharging, discharging to open surface water, or partial recycling of treated wastewater.

The SF wetlands are designed to maintain water (or wastewater) level below the surface of the media (rocks, gravel), so there is no free opening to the atmosphere. Depending on the scheme of the design and the operation of the system, the SF wetlands might be known as: vegetated submerged bed (VSB) flow, root zone method (RZM), vegetated rock-reed filter, microbial rock filter or hydrobotanical systems.

The operation of both systems, FWS and SF, can be compared to the microbial activity in trickling filters, RBC units, or the various types of wastewater land treatment (REED et al. [12]). Thus they can be treated as a variation of biological reactors.

The transport and transformation of pollutants through the wetland ecosystem (both natural and constructed) is known as biogeochemical cycling with various, interrelated processes: physical, chemical and biological. Since a constructed wetland (especially FSW type) typically mimics the behaviour of natural wetlands in design and function, water entering the system experiences settling as the primary physical process, then undergoes biogeochemical transformation.

Aquatic plants used in constructed wetlands vary widely, depending upon climate and soils, but the most common emergent plants are reeds, cattails, rushes, bulrushes and sedges. Regardless of plant type, ultimately natural processes will cause certain plants to become dominant. The emergent plants have the ability to uptake oxygen and other needed gases from the atmosphere through leaves and stems above water and transport them to the roots. Thus the soil zone in immediate contact with roots can be in aerobic and anaerobic environments. Although the submerged plants can uptake nutrients and other constituents, it seems that their most important function in CWWTs is to serve as the substrate for the microorganisms attached. The microbes in constructed wetlands can help to reduce high levels of BOD, suspended solids, nitrogen and significant levels of metals, trace organics and pathogens.

When considering which type of wetlands to construct, the initial design characteristics of both the FWS and SF are closely related. Initially considered in the preliminary design and site characteristics are topography, soil characteristics, existing land use, flood hazard and climate (METCALF and EDDY [10]). A slight grade, about one percent, is favoured for the SFs, while a fairly level grade is desirable for the FWS system. Uniform topography is desired for both and rarely is a grade of more than five percent considered because of earthwork costs.

In consideration of soil, a low permeability is desired. This surface and subsurface permeability rate is typically less than 0.51 cm per hour. This low rating is to prevent percolation and subsequent rapid filtration of the wastewater since it is generally desirable to treat the water above the soil.

The vegetation used is the point that the considerations of the SF and FWS systems begin to diverge. For the FWS system the vegetation is determined by the depth of water, while for the SF system the vegetation is determined by the depth of root and rhizome penetration. Bulrushes grow well at depths of 5–25 cm, reeds along the shore and in the water up to 150 cm, and cattail rhizomes and root extend up to 30 cm. This depth is compared to that of reeds growing up to 60 cm and bulrushes up to 76 cm. Reeds and bulrushes are selected for the SF system since they allow use of deeper basin penetration (METCALF and EDDY [10]).

In the design of an SF system, the dimensions are determined as follows (REED [12]):

$$A_s = \frac{Q(\ln C_0 - C_e)}{K_t dn},$$

where:

Q – daily flow rate,

C_0 – influent BOD,

C_e – effluent BOD,

d – submerged depth controlled by plant selection,

n – the bed porosity,

K_t – the temperature/porosity dependent constant which is determined from the equation:

$$K_t = K_{20} 1.1^{(T-20)},$$

where:

K_{20} – the rate constant at 20 °C,

T – the operational temperature.

Also useful in the design of wetland systems is the detention time. For the SF system the detention time is found as follows:

$$t' = \frac{LWad}{Q},$$

where:

t' – the theoretical detention time,

L – basin length,

W – basin width,

a – the porosity of basin medium;

$$t = \frac{l}{k_s S},$$

where:

t – the actual detention time,

k_s – the hydraulic conductivity,

S – the basin slope.

All these factors must be considered important in the design of such a treatment system. A compromise between the factors must be achieved to reach the most efficient SF wetland system.

3. CURRENT APPLICATIONS

The number of CWWTs continues to grow as their applications become better understood and more widely accepted. As of 1991, there were approximately 250 systems in the United States (WATSON [19]).

Constructed wetland systems may be used as closing segments following preliminary treatment, or they can serve as treatment systems by themselves. The concentration of the systems, their types and distributions are shown in tables 1 and 2 (according to REED and BROWN [13]). Although the data recorded are not displayed for the last four years, table 2 indicates that the SF systems have become more popular than FWS systems. Although SF systems are typically limited in size, they have the advantage of the water level being below the media surface, thereby eliminating odour and insect vector problems. Depending upon the application, the SF and FWS systems can be found operating in parks and other public places and, in fact, can become an aesthetic asset to the landscape.

Table 1

Number of operating systems, inventory data from 1990
(adapted from REED and BROWN [13] data)

Number of systems	State
Less than 5	Oregon, California, Idaho, Nevada, Colorado, Kansas, Oklahoma, Texas, North Dakota, Michigan, Wisconsin, Florida, Kentucky, Georgia, Virginia, New Hampshire, New York, Pennsylvania, Vermont
Between 5 and 10	Washington, Montana, Minnesota, Wyoming, South Dakota, Nebrasca, Iowa, Missouri, Illinois, Ohio, West Virginia, Maine, Utah, Arizona, New Mexico, Arkansas, Alabama, Kentucky, North Carolina, South Carolina, Indiana, Connecticut
More than 15	Mississipi, Louisiana

Table 2

Types of constructed wetlands, distribution in the United States
(adapted from REED and BROWN [13] data)

Type of constructed wetland	State
Subsurface flow (SF)	Idaho, New York, Pennsylvania, New Mexico, Texas, Oklahoma, Louisiana, Arkansas, Tennessee
Free water surface (FWS)	Oregon, California, Nevada, Arizona, Colorado, Kansas, Missouri, Iowa, Wisconsin, Michigan, Georgia, Florida
SF and FWS	Washington, Montana, Wyoming, Nebraska, Utah, Minnesota, Illinois, Ohio, Pennsylvania, Kentucky, Virginia, North Carolina, South Carolina, Maine, New Hampshire, Vermont

The size of constructed wetland is closely related to the expected load of wastewater, but in general the FWS systems are larger than SFs (5–11,000 $m^3 \cdot d^{-1}$

and 200–76,000 $m^3 \cdot d^{-1}$, respectively). The two types have different treatment requirements. FWS wetlands might be designed to: (1) lower BOD and TSS (Total Suspended Solids) levels only; (2) furnish nitrification–denitrification processes (removal of nitrogen from the system); (3) provide tertiary wastewater treatment (removal of nitrogen, phosphorus, and trace some pollutants); or (4) serve as retention systems. In contrast, there is not as great an expectation for SF systems. They are mostly designed to decrease concentration of BOD, TSS and some ammonia.

4. SELECTED EXAMPLES

4.1. WASTEWATER

The use of wetlands for wastewater disposal is not new, but the use of constructed wetlands for wastewater disposal is relatively recent. The interest in wetlands, both natural and constructed, for this purpose stems from a number of factors (SEREICO and LARNEO [16]):

– public demand for more stringent wastewater effluent standards,

– rapidly increasing costs of construction, operation and maintenance of conventional wastewater treatment facilities,

– realization of the natural treatment functions of wetlands,

– appreciation of aesthetic and environmental benefits of wetlands.

As indicated previously, numerous applications of CWWTs now exist, and a majority of them are small-scale, relatively low-cost applications for domestic waste, ranging in size from individual households to entire communities. As an example, Union, Mississippi, a small rural town of about 2,000 inhabitants, has installed a CW facility for about $500,000, or less than half the cost of building a new treatment plant (MOOS [11]).

Two substantial CWs for wastewater treatment are in Orlando, Florida. One system was designed and constructed for Orange County, and has been in operation since 1986. The relatively simple design consists of created wetlands planted with selected herbaceous vegetation and integrated with natural wetlands. One-half of the system is an overland-flow type created wetland in which wastewater is collected and redistributed into the second half, also an overland-flow type created wetland. Both halves are integrated with natural wetlands. The recycled wastewater ultimately discharges into a small creek. The system covers 120 hectares and was initially operated at 11,300 $m^3 \cdot d^{-1}$, with an ultimate design capacity of 23,500 $m^3 \cdot d^{-1}$ (BEST [1], LESZCZYŃSKA and DZURIK [4]).

The second system, designed for the City of Orlando, is about 480 ha and ultimately designed to treat 60,000–90,000 $m^3 \cdot d^{-1}$. It is divided into three functional portions. The first one-third is the managed portion of the system allowing for various management options; it is planted in cattails giant bulrush to maximize nutrient removal. The second portion is a mixed emergent marsh wetland divided into two discrete cells to allow for some flexibility; it is planted with several marsh species with diverse functions. The final portion of the system is *to provide final polishing of the water, serve as a buffer, and provided flora and faunal habitat* (BEST [1]). The overall CW system is named 'Orlando Wilderness Park' and serves as a major wetland and recreational facility while meeting all regulatory limits for discharge set by the state.

4.2. STORMWATER

In 1990, the U.S. EPA published final regulations for the National Pollution Discharge Elimination System (NPDES) stormwater discharge permits, thereby implementing requirements of Section 405 of the Water Quality Act of 1987. The regulations require certain industries and municipalities to obtain NPDES stormwater permits for all storm sewers that drain into public waterways. Although the municipal permits apply only to communities of over 100,000 population, it is conceivable that at some future time, the threshold level would be lower. Aside from specific legal requirements, it makes sense for communities of all sizes, as well as agricultural and industrial areas, to treat stormwater runoff, for this non-point contaminant is now the major source of water pollution, especially from urban areas. Land use changes associated with urban development alters the hydrology by changing peak flow, total runoff and water quality. Most water quality degradation results from the 'first flush' effects of runoff, which flushes the surface of contaminants that have accumulated. In Florida, the first flush is equal to the first 2.5 cm of runoff and carries 90% of the pollution load from a storm event (LIVINGSTON [9]).

A number of management practices can be used to reduce pollutants from stormwater runoff, but natural wetlands, wet retention systems and constructed wetlands are becoming primary treatment processes for stormwater runoff. Many constructed wetland systems for stormwater runoff have been built in Florida in the past ten years (LIVINGSTON [9]). The most common type is a wet detention system with a permanent water pool, temporary stormwater storage area above the permanent pool, and a littoral zone planted with native aquatic plants.

An outstanding example of a CW for stormwater runoff treatment is the Lake Jackson Restoration Project in Tallahassee, Florida, and an experimental project with major funding from the U.S. EPA.

Research in which we were involved four years ago focussed on the effectiveness of constructed wetlands for treating municipal wastewater. The experimental system, located in Orange County (Orlando), Florida, was put in use at the beginning of 1987. It was monitored from the beginning of the operation, and still is under control. This system, comprising 120 ha of artificial and natural wetlands, was designed as a receiver of secondary treated wastewater. The constructed wetlands, created as a FWS type, were adjacent to natural marshes and were serving as major treatment areas and buffer zones at the same time (BEST [1], [2]). A primary objective of the research was to evaluate the chemical and hydrological responses of the experimental system to hydraulic input. Monthly, simultaneous monitoring at 57 points was conducted of major parameters important for estimation of water quality (pH, conductivity, temperature, DO, TSS, BOD, nitrogen, phosphorus metals, bacteria) for the whole system and for the control wetland (not connected with the system; data used as a base line). Results indicate that a constructed wetland can significantly improve water quality. Results of the experimental wetland evaluation together with actual constructed wetland design for wastewater and stormwater runoff applications show that a system can be designed to treat simultaneously stormwater and pretreated municipal wastewater (LESZCZYŃSKA and DZURIK [8]).

5. SIMULTANEOUS TREATMENT OF WASTEWATER AND STORMWATER

The design of a constructed wetland to handle wastewater and stormwater runoff at the same time has a number of basic concepts that should be taken into account:

1. The type (and configuration) of a proposed CW can be designed as a single system with different treatment functions, or it can be attached to the existing wetlands, but in both cases it should be a free water surface type (FWS). This construction, even bigger in size, might be easier to maintain and have the capacity to store unexpected rainfall. In recent years, the SFs became more popular in the U.S., but they cannot be used for stormwater runoff or treatment of raw wastewater. Most of the SFs have experienced clogging problems (HAMMER, 1993), so they can be recommended only for some water polishing for effluent with low concentration of nutrients and for other pollutants that require adequate dissolved oxygen levels. Components of the system will depend on expected pollutants and their concentrations. For example, the marsh type of constructed wetland is the more effective for BOD, TSS and pathogen removal; ponds and overland flow meadows are most efficient at transforming ammonia to nitrogen gas (better conditions for oxidation) (HAMMER, 1993).

2. Design criteria can address predictable and unpredictable factors. Predictable factors are the flow and waste load of wastewater; this component can be designed with reasonable accuracy. On the other hand, stormwater runoff is unpredictable in frequency and magnitude. The discharge should be treated as a mixture of point source pollutants (municipal wastewater) and non-point source (NPS) pollutant

(stormwater runoff). Non-point discharge can be estimated probabilistically from weather data, typical of certain regions and climates. Possible types of pollutants and their concentrations will depend on the region. The NPS contributes over 65% of the total pollution load to U.S. inland surface water [17]. Sources include urban stormwater, runoff from industrial sites and mines, diffuse agricultural runoff from pastures and row crops. In rural communities, with heavy farming, the stormwater runoff may contain excessive amounts of nutrients from fertilizers and different types of pesticides. For urban communities, pollutants in stormwater can come from nearby industry, from the atmosphere and they might be washed out of the streets, so they may have an elevated level of metals, oil, acids and other pollutants. The comprehensive study (U.S. EPA [17]) of urban runoff in 22 cities showed that the average concentrations of certain metals are as follows: copper – 34 $\mu g \cdot dm^{-3}$, lead – 144 $\mu g \cdot dm^{-3}$ and zinc – 160 $\mu g \cdot dm^{-3}$. The concentration of each metal exceeds its permissible level in more than half of the collected samples.

3. Additional treatment may be needed before discharging to wetlands. Municipal wastewater should be subjected to some pretreatment, at least the primary step. Before discharging to the wetland, solids, grit and debris should be removed in settling basin, or single- or multistage lagoon system. Providing additional aeration in the wetland may decrease necessary retention time, as well as to help to increase effectiveness of some of oxidation reactions. A system of small cascades (where is possible without extra cost) may decrease the intensity of additional aeration and total cost of construction. Generally, the location of the wetland should provide gravity flow for wastewater to the system, and through the system to eliminate the cost of the pumping and maintenance.

4. The type of soil, mineral, organic or clay may be important when metals are expected as pollutants, and/or when there is a higher concentration of nutrients. Additional lining such as clay or synthetic fabric will prevent leakage from the wetland to groundwater.

Benefits of a combined wastewater/wetland system are several. It is relatively low cost for operation and maintenance as well as for initial construction, and it has low energy requirements. The organic part of wastewater pollutants will be diluted by stormwater, and biota should stay unharmed. A significant community benefit is that the system can be designed as a landscape feature and add to the aesthetic value of the surrounding area. An important operating benefit, especially in relatively dry areas, is that the system will always be wet because of the continuous inflow of wastewater.

Although there are benefits to a combined wetland system, limitations also exist. In dry seasons, wastewater discharge may dominate and cause problems with treatment. Partial recycling of treated wastewater might be considered for the system for further dilution, but this will require an additional pumping system. From another point of view, constructed wetlands that depend only on stormwater flow may suffer during dry seasons. During dry seasons, an alternate source of water is required. Wastewater discharge may help to save wetlands treatment functions.

One example of a combined wastewater/stormwater constructed wetland system is for Monticello, a small community of less than 10,000 inhabitants in north Florida. The CW used in Monticello is for tertiary treatment of municipal waste from a typical secondary treatment plant. Because of increasingly stringent effluent standards for water quality, an advanced treatment system was needed prior to discharge into nearby surface waters. The treatment of choice was to construct an overland flow and constructed wetland tertiary treatment system. The size of the site for tertiary treatment and stormwater runoff is over 24 ha, about 2/3 of which is for the CW component. According to a preliminary investigation, *the volume of flow must include both the design flow of 3785* $m^3 \cdot d^{-1}$ *plus all the stormwater runoff which will naturally pass through the wetland* (DS&N [5]). The amount of stormwater runoff was estimated for the entire 531 ha contributing watershed, and the total amount of runoff was converted to an average daily amount and then added to the design flow to estimate a total daily flow. Although this is not the stormwater runoff for the entire community, it represents a substantial portion whose basin coincides with the site for the tertiary wastewater treatment facility.

6. SUMMARY AND CONCLUSIONS

We have shown that constructed wetlands are becoming increasingly important as a technology for improving water quality, especially for small communities with low budgets. CWs can help small communities to meet more stringent water quality standards at a reasonable cost. At the same time, a constructed wetland can be a visual and recreational asset to a community by incorporating good landscape design.

The effluent from CWs is cleaner than the influent and can be used for recreation, agricultural irrigation, industrial processes, groundwater and stream augmentation and possibly as a supply of drinking water. CWs can also serve as park areas with habitats for fish and migratory birds, as was done in the cities of Orlando, Florida and Arcata, California.

One of the limitations of CWs is the amount of land required. The EPA study suggested that *wetland systems are most suitable for communities with wastewater flows of less than 7,5560* $m^3 \cdot d^{-1}$ *that require secondary, advanced secondary, or advanced treatment* (HYDE [7]). As an example of the size of a modest CW, the system in Crowley, Louisiana, was designed to treat up to 15,100 $\mathrm{m}^3 \cdot \mathrm{d}^{-1}$ of domestic wastewater and to serve a population of about 28,000 – the CW requires approximately 31 ha of land. An obvious outcome is that most CW systems are in rural communities where land is relatively plentiful and inexpensive (MOOS [11]).

ACKNOWLEDGEMENTS

This work was supported in part by the National Science Foundation Grant RII-8902064, JSU/Earth Observing System Program – NASA Subcontract No. NCA TSU-JSU-TASK13-93-001 and by the Department of Energy, Contract No. DE-LGO5-86EA75274.

REFERENCES

[1] BEST G.R., *Wetlands Ecological Engineering: An Approach for Integrating Humanity and Nature Through Wastewater Recycling Through Wetlands*, Proceedings 7th NABS Workshop, 1994.

[2] BEST G.R., *Natural Wetlands – Southern Environment: Wastewater to Wetlands. Where Do We Go From Here?* Aquatic Plants for Wastewater Treatment and Resource Recovery, Magnolia Publishing, Inc., 1987.

[3] Camp Dresser and McKee Inc., *Addendum to December 1985 Wetland Exemption Background Monitoring Report, Eastern Service Area Wastewater Treatment Facility, Phase III*, Orange County Public Utilities Division, Orlando.

[4] CWWT News, *Treatment Comparison*, CWWT News, I(1), Fall 1992, Civil Engineering, Colorado State University, Ft. Collins, CO., 1992.

[5] DS&N, Consulting Engineers, *Monitoring Plan for City of Monticello, Wetlands Effluent Discharge System*, HAMMER D.A., 1988, *Designing Constructed Wetlands Systems to Treat Agricultural, Non-point Source Pollution*, Ch. 4 of Created and Natural Wetlands for Controlling Non-point Source Pollution, C.K. SMOLEY, 71, 1993.

[6] HAMMER D.A., *Constructed Wetlands for Wastewater Treatment, Municipal, Industrial and Agricultural*, Lewis Publishers Inc., Chelsea, Michigan, 1989.

[7] HYDE H.C., ROSS R.S., DEMGEN F., *Technology Assessment of Wetlands for Municipal Wastewater Treatment*, U. S. Environmental Protection Agency, Cincinnatti, 1984.

[8] LESZCZYŃSKA D., DZURIK A., *Tertiary Wastewater Treatment Through Constructed Wetland Ecosystems*, Environment Protection Engineering, No. 1–2 (1992), Vol. 18.

[9] LIVINGSTON E., *Use of Wetlands for Urban Stormwater Management*, [in:] Donald Hammer (ed.), *Constructed Wetlands for Wastewater Treatment*, Lewis, 1989.

[10] METCALF and EDDY, Inc., *Wastewater Engineering, Treatment, Disposal and Reuse*, McGraw-Hill Publishing Co., New York 1991.

[11] MOOS, SHAWNA, *More Than Just Sewage Treatment*, Technology Review, August 1993.

[12] REED S.C. et al., *Natural Systems for Waste Management and Treatment*, McGraw-Hill Book Co., New York 1988.

[13] REED S., BROWN D.S., *Constructed Wetland Design – The First Generation*, Water Environment Research, 64(6), 1992.

[14] RUBIN A.J., *Chemistry of Wastewater Technology*, Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan 1978.

[15] SANKS L . et al., *Land Treatment and Disposal of Municipal and Industrial Wastewater Treatment*, Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan 1975.

[16] SEREICO P., LARNEO C., *Use of Wetlands for Wastewater Treatment*, [in:] Donald Hammer (ed.), *Constructed Wetlands for Wastewater Treatment*, Lewis 1989.

[17] U.S. EPA, *Focus on Non-point Source Pollution*, the Information Broker, Office of Water Regulations and Standards, Non-Point Sources Control Branch, Washington, D.C., November 1989. U.S. EPA, 1983, *Results of the Nationwide Urban Runoff Program*, Vol. 1 – Final Report. WH-554, Water Planning Division, USEPA, Washington, DC.

[18] U.S. House of Representatives, Committee on Public Works and Transportation, 1992, Hearing on *The Role of Constructed Wetlands and Other Alternative Technologies in Meeting the Wastewater Treatment Needs of Rural and Small Communities*, August 4, 1992, Washington D.C.

[19] WATSON J.T., *Constructed Wetlands for Municipal Wastewater Treatment: State-of-the-Art*, unpublished paper, Tennessee Valley Authority, 1992.

ZASTOSOWANIE SZTUCZNYCH MOCZARÓW DO JEDNOCZESNEGO OCZYSZCZANIA ŚCIEKÓW I WÓD DESZCZOWYCH

Sztuczne moczary są jednym z możliwych sposobów zastosowania naturalnych systemów do oczyszczania ścieków. Dodatkowe zainteresowanie tymi systemami zostało spowodowane wejściem w życie nowych przepisów federalnych, dotyczących wód deszczowych, a także zaostrzeniem norm jakości wody. Zastosowanie sztucznych moczarów do przetrzymywania i oczyszczania wód deszczowych wydaje się interesującą alternatywą. Decyzja o zbudowaniu moczarów zależy oczywiście od wielu czynników, jak strefa klimatyczna, obciążenie ściekami, dostępne tereny pod budowę i ich wielkość oraz zaplanowany budżet.

W artykule zaprezentowano przegląd systemów sztucznych moczarów na terenie Stanów Zjednoczonych. Przedstawione kategorie to: oczyszczanie ścieków z terenów rolniczych, miejskich, przemysłowych i wód deszczowych. Informacje zawarte w pracy pochodzą z literatury, programów komputerowych, agencji stanowych oraz z prywatnych rozmów ze specjalistami. Odpowiednio zaprojektowane sztuczne moczary mogą być rozwiązaniem problemów w małych miejscowościach, dysponujących niewielkim budżetem.

ПРИМЕНЕНИЕ ИСКУССТВЕННЫХ БОЛОТ ДЛЯ ОДНОВРЕМЕННОЙ ОЧИСТКИ СТОЧНЫХ И ДОЖДЕВЫХ ВОД

Искусственные болота являются одним из возможных способов применения природных систем для очистки сточных вод. Добавочная заинтересованность этими системами была вызвана установлением новых федеральных правил, касающихся дождевых вод, а также обострением норм качества воды. Применение искусственных болот для задерживания и очистки дождевых вод кажется интересной альтернативой. Решение о постройке болот зависит от многих факторов, как климатическая зона, нагрузка сточными водами, доступные территории для построения болот, их размер, а также планируемый бюджет.

В статье представлен обзор искусственных болот на территории США. Представленные категории это: очистка сточных вод из земледельческих, городских и промышленных районов, а также дождевых вод. Эти информации, содержащиеся в настоящей работе, происходят из литературы, компьютерных программ, от штатных агентств, а также вытекают из разговоров со специалистами. Запроектированные соответствующим образом искусственные болота могут быть решением проблем в малых местностях, имеющих небольшой бюджет.