CONSTRUCTED WETLANDS – A NEW APPROACH FOR THE TREATMENT OF MUNICIPAL WASTEWATER IN VOJVODINA PROVINCE

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Abstract

Wastewater is treatable in a number of different types of constructed wetlands. This technology is now entering a phase in its development where it can provide wastewater treatment in a wide range of circumstances. Unfortunately, this popular method still is not applied in our country. The first attempt is just going on in Vojvodina Province. This part of country is with good conditions for municipal wastewater treatment by constructed wetland. There are 85.9% of communities with number of people between 1000 and 5000. From the other side, there are convenient types of soils around the communities. This paper deals with details of the first constructed wetlands in Glozan. Glozan is a village with 2275 people, and sewage system, without any industry inflow. Constructed wetland wastewater treatment system followed by Cooper and Clarke proposition is applied.Their designed/manmade system aimed at achieving removal of pollutants as observed to take place in natural system. Typical arrangement for combination horizontal and vertical flow is applied. The first experience in design, building and observation of work will be discussed in this paper.

Introduction

During the last several decades we have witnessed the application of a new, entirely natural and ecological method of wastewater treatment – constructed wetlands method, representing a combination of biological, chemical and physical processes. In contrast to the previous expensive and technically complicated solutions and dirty technologies, this method is far less expensive, simpler and cleaner. The method was originated in England and nowadays is used worldwide (USA, Australia, Germany, Netherlands, Italy, Egypt, India, even in the northernmost Norway, etc.).

The method essentially consists of using wetland plants (macrophytes) to treat wastewater; the plants through their stems ensure the presence of significant amounts of air (oxygen) in the zone of their root systems, enabling thus development of aerobic bacteria colonies in the root zone (2). Bacteria use the harmful matter from the wastewater for their nutrition (similar to the situation in the aeration tanks of classical treatment equipment) and thus remove it from the water. Part of this matter is used by plants for their growth. In addition to their role in soil aeration macrophytes have a number of other roles: influence stability of the upper soil layer of the bottom, ensure favourable conditions for physical filtration, act preventively on soil curdling, provide protection against negative effects of wind and cold, give pleasing and natural appearance of the system as a whole.

Constructed wetlands method has found its best application in treatment of sewages of smaller settlements, as well as agricultural wastewaters and industrial wastewaters after their primary or secondary treatment (5).

The quality of the water after wetland treatment is such that it can be discharged into water courses of category II of water quality (4).

The development of wetland technology was gradual. It started first with natural bogs under reeds, then by forming artificial fields with horizontal and vertical flow, to arrive finally at the properly efficient solutions, that is the hybrid system of constructed wetlands.

Wetlands Classification: Constructed wetlands for wastewater treatment can be classified as follows (5):

- wetlands with overland flow
- wetlands with subsurface flow,

whereas the latter can be with horizontal and vertical flow.

Overland Flow Systems: Systems with such flow are designed based on constructing of long narrow canals with planted wetland plants. The wastewater inlet is at one end of the canals and the effluent outlet is at the opposite end. The wastewater treatment is carried out by aerobic and anaerobic microorganisms present as epiphytes on the aboveground part of the stem and dead plants. Oxygen is transported through the green stem parts. This method gives satisfactory results only in regard of total suspended solids (TSS) and biological oxygen demand (BOD_5), whereas the results in removing nitrogen and phosphorus are not satisfactory (1).

Subsurface Horizontal Flow Systems: These systems are constructed in the form of rectangular lagoons, planted mostly with reeds (*Phragmites australis*), with the walls covered with some impermeable membrane. The role of reed in wastewater treatment is to support the process by its underground part of the root zone. Oxygen from atmosphere is transported through the hollow reed stem to the root zone, from where it partly penetrates to the microzone around the root (the rhisosphere) populated with aerobic microorganisms that decompose organic matter. Also, the root and rhizome by their growth create macropores in the soil and thus maintain its hydraulic conductivity (1).

A shortcoming of this system appears in the case of using natural soil as substrate, whereby the hydraulic conductivity is insufficient because of poor porosity. Hence, the water flows fast over the surface, shortening thus the residence time of wastewater and lowering the possibility of its purification. Also, the amount of oxygen is insufficient, so that percentage of nitrogen removed is not satisfactory. This system too exhibits good effects in removing TSS and BOD_5, whereas the removal of nitrogen and phosphorus is not satisfactory (1).

Subsurface Vertical Flow System: In this system the natural substrate is replaced by gravel in which macrophytes, mostly reeds, are planted. Wastewaters are treated by filtration through this medium and collected in the drainage pipes placed at the bottom and thus conducted to the outflow canal. The system functions as follows: the rhizomes and reed roots grow intensively through the gravel and enable high hydraulic conductivity; in the richly branched root zone there are high populations of aerobic bacteria; oxygen transport is significantly enhanced and aeration in general is far more efficient. Thus, the purification process is accelerated (4).

The use of this type of constructed wetlands ensures satisfactory results in the removal of TSS, BOD_5 and nitrogen, whereas the results for phosphorus are not satisfactory, as the adsorption of this element is low because of insufficient residence time and large size of gravel particles.

Hybrid Systems: These systems represent a combination of constructed wetlands with vertical and horizontal flow, using advantages of the both systems. They enable more efficient removal of TSS, BOD_5, nitrogen, and phosphorus. Various combinations and types of solutions are possible, which are adjusted to all the conditions on the terrain.

In our country, the method of wetlands has not been applied yet. First attempts are currently made in the Province of Vojvodina, in the settlement Glozan. Vojvodina represents an ideal territory for the application of this method as its 85.9 % of settlements has between 1000 and 5000 inhabitants. In their surroundings, the settlements have marshy lands with reeds growing as weed.

Glozan is a settlement that is by its natural, demographic and sociological conditions ideal for the application of this method. The number of inhabitant, essential for the dimensioning of the sewage system and treatment plant, is 2275 PE (population equivalent). In view of the fact that there is no experience in applying this method in our country, this first plant has to be of a research character, to monitor the results achieved in defining the necessary parameters for dimensioning wetlands under the conditions in Vojvodina (4).

Glozan-constructed wetland

On the Glozan location a plant has been constructed for sewage treatment of the hybrid type, involving a combination of horizontal, vertical and lateral (*vide infra*) flow, according to the proposition of Cooper and Clark (6).

In addition to the constructed wetland the system will contain the following elements:

- field embankment at least 0.5 m high
- outer ditch 1.5 to 2.0 m deep, enclosing the embankment, to protect the wetland from the outer waters and higher groundwaters
- outer green belt formed of willow (*Salix* sp.) and elder (*Sambucus nigra*), plants that are also known as good wastewater purifier
- two rows of high trees such as poplar (*Populus tremula*) encircling the green belt. These plants use large amounts of water and by lowering the water table protect the wetland.

Calculation and Dimensioning of the Objects: The input data needed for dimensioning of the objects making constituent parts of the process of wastewater treatment were adopted on the basis of standard quality and quantities of wastewater of the settlement of rural type, containing no industrial wastewaters. Measurement data are still lacking as the system has not been completed yet.

- Competent number PE (population equivalent): 2275
- Maximum daily flow of wastewater : 756 m^3/day
- Organic loading (BOD_5): 168 kg/day
- Total suspended solids (TSS): 210 kg/day
- Chemical laoding (COD): 434 kg/day
- Total nitrogen (N): 34 kg/day
- Total phosphorus (P): 6 kg/day

The area of the wetland can be determined using equation of Paul Cooper (6):

$$Ah = \frac{Q_d\,(\ln C_o - \ln C_t)}{k_{BOD}}$$

Where:
Ah - area (m^2)
Q_d - average flow (m^3/day)

C_o -average BOD of feed (mg/l)
C_t - average BOD of effluent (mg/l)
k_{BOD} - coefficient whose value ranges from 0.22 to 0.56. The value which will be accepted gives larger necessary area of wetland and higher level of safety.

For settlement Glozan:

$$Ah = \frac{756(\ln 222 - \ln 20)}{0.22}$$

Ah = 8271 m^2 it is 2.95 m^2/PE

It is accepted 3.0 m^2/PE or in total 8400 m^2.

Wetland Location: The wetland construction is planned in the Danube inundation plane at the southern side of the settlement. The terrain is swampy and thus suitable for reed growth. Being a depression, it enables gravitational flow of the wastewater to the treatment site. Inundation has been regulated by constructing drainage canals, so that no special flood protection measures are to be undertaken. To one of these drainage canals is also discharged the water after its treatment.

Wetland Internal Structure: Total area of the wetland system of 8400 m^2 is divided into three ponds of different areas and dedication, connected in series so that water passes by overflowing through all three ponds. The system consists of settling pond, purification pond and the pond improvement of treatment effects.

Settling pond is the first in the series and wastewater comes to it after passing through a coarse grid placed in the dividing chute to collect larger pieces of wastes from the water. In fact, two such ponds, covered with reeds, are envisaged, each of an area of 1000 m^2. While one pond is in operation the other is in preparation. The purpose of these ponds is to separate larger part of settlable waste matter from the water. When one field is saturated, the other is put into work, while the former is revitalized. The water residence time is more than 14 hours.

Purification pond covers an area of 5000 m^2. Parallel gravel beds, 0.6 m wide and 0.6 m thick, are constructed in succession with 1.0 m wide strips of natural substrate between them. A gravel bed consists of three layers. The bottom layer (15 cm) is of natural gravel and a drainage pipe is placed in it to conduct the filtered water to the concrete collecting canal at the end of the wetland. The next layer (30 cm) is formed of the excavation earth. The third, surface layer, is made of gravel and reed clods are planted in it. Along the natural substrate strips, horizontal flow takes place, though there exists also lateral purification. Namely, the reed roots grow fast both in depth and width through the porous substrate (gravel). Strong rhizomes from the side clods penetrate to the strips without gravel, making thus the natural substrate more porous. Fecal water can also penetrate with the aid of rhizomes and reed roots through the gravel beds to the natural substrate strips, resulting in an intensive lateral purification of wastewater in the reed root zone. The internal structure of the wetland is designed so that the gravel beds serve as the sites of vertical purification. Then, by a slow flow through all the beds proceeds horizontal and lateral purification, whereby the latter is more intensive in the strips of natural substrate. The water residence time in this pond is more than 3 days.

The pond for improvement of the purification effects comes after the purification pond. The inflowing water is with essentially reduced concentrations of original polluting matter. This pond also consists of successive gravel beds (0.6 m in depth and width, with drainage pipes) and the strips of natural substrate. Here, the water achieves the desired degree of purification and obtains satisfactory characteristics to be collected by overflow in the collecting canal and conducted to the recipient.

Conclusions

The paper describes a first attempt of introducing constructed wetlands method in the Province of Vojvodina. With its natural characteristics and settlements of optimal size, Vojvodina represents an exceptionally suitable region for the application of this inexpensive natural and ecological method. In the future, it can be expected an expansion of its application as the majority of settlements have not resolved yet the problem of sewage treatment.

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