ENERGY-EFFICIENT WASTEWATER TREATMENT TECHNOLOGIES IN CONSTRUCTED WETLANDS

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ABSTRACT

Usually in wastewater treatment plants the removal of organic matter is ensured in aerotanks in biochemical reactions where activated sludge in presence of oxygen transforms the organic matter. The quantity of organic matter in water can be determined as the biochemical oxygen demand in five days (BOD). BOD in village municipal sewage is around 250 mg l^{-1} or 65 g per day from each resident. It means that 1.7 kg of oxygen is needed for mineralizing one kg of organic matter. Therefore, it can be concluded that high oxygen demand is required to mineralize organic matter using aerotanks. With a compressor and aeration discs or tubes the oxygen in the form of air is provided to aerotank. To reduce electricity consumption in wastewater treatment, we present to adapt natural conditions. Mineralization of organic matter in constructed wetlands performs basing on bacteria activity in presence of oxygen. The main difference is the method for oxygen supply. In constructed wetlands oxygen demand provides the plants growing above the filter material and it consumes no electricity. Constructed wetlands can be designed with different water flow in filter material – horizontal flow wetlands, vertical flow wetlands and shallow ponds with plants.

Keywords: Constructed wetland, wastewater treatment

INTRODUCTION

Nowadays, people tend to focus on nature and environment protection, as far as possible giving up excessive use of chemicals in everyday life. A sustainable use and development of natural resources is one of the environmental retention initiatives. Wastewater generation is an integral part of human life processes, including both domestic waste water and industrial waste water and rainwater drainage, if they contain anthropogenic pollutants - dust, oil, soil particles. The level of waste water pollution depends on the concentration of pollutants and waste water composition. Natural processes are the most environmentally friendly way to treat man-made waste. However, not necessarily the natural treatment methods give the desired degree of extraction and are able to treat waste water fast enough. Treatment plant adaptation to the situation is often associated with the use of additional mechanical plant or electrical energy use, which increases the maintenance costs.

In Latvia for wastewater treatment mostly biological wastewater treatment plants are used – aerotenks with activated sludge as the main organic matter reducer. Activated sludge requires solid air or pure oxygen supply to support the living and usually we ensure it with compressors or oxygenating pumps. About 15 - 20 m^3 of air per 1 m^3 of wastewater is used in this mineralization process. Consequently, treating 1 m^3 of typical wastewater with coercive aeration consumes 15 – 20 m^3 of air, what means 0.264 – 0.352 kW per each m^3 of wastewater depending on the power of the air compressor.

In further points an opportunity to purify municipal wastewater close to natural processes, not using additional machinery or electrical energy is described. In order to make more sustainable wastewater treatment and to save electricity, it is possible to choose a wastewater treatment method that works due natural processes and does not require special operation. These requirements meet the worldwide known and widely used extensive method to different quality wastewater treatment in constructed wetland. If there is an additional territory it is possible to change the present energy-intensive wastewater treatment plants to constructed wetlands, adjusting the wetland area, flow direction and other parameters to the actual situation. The operating principle of constructed wetland is using the natural degradation processes and nutrient uptake. (Langergraber, 2006) Several factors affect the ability of constructed wetlands to retain nutrients including alternate dry (aerobic) and wet (anaerobic) conditions, hydraulic retention time (HRT), influent nutrient concentration, water depth, hydraulic loading rate, emergent vegetation, water chemistry, and soil type (Chavan, 2008). As shown by studies, for subsurface flow wetlands primary treatment, at a minimum, it is required to remove settle able and floating solids prior to the wetland bed. This is typically provided through the use of settling tanks (Kadlec, 2008; Reddy, 2008). As defined by Vymazal (2003) wetlands are known to act as biofilters through a complex of physical, chemical and biological factors which all participate in the reduction of the number of bacteria.

MATERIALS AND METHODS

Site description

Using constructed wetlands as municipal wastewater treatment is a new discipline in Latvia. Four constructed wetlands (Tinuzi, Tervete, Birzi, Pedvale) implemented in Latvia from 2003 to 2005 work properly and effectively. For the referred years data are available on BOD, COD and suspended solids, also phosphorus and nitrogen concentration in the wastewater before and after treatment in constructed wetlands. The major design parameters are presented in Table 1. All these constructed wetlands were designed to treat mechanically prepared municipal wastewater. The mechanical pretreatment is provided by the settling cameras with volume for 3 day effluent discharge.
As the monitoring data show, at the outlet of constructed wetlands wastewater is purified in accordance with the existing legal requirements of Latvia, i.e., BOD does not exceed 25 mg/l, COD does not exceed 125 mg/l, and suspended solids are less than 35 mg/l.

Table 1

Major design parameters

Location	Start of operation (year)	Population equivalent (PE)	Wetland area (m^2)
Tinuzi	2003	190	960
Tervere	2004	240	1200
Birzi	2005	400	2000
Pedvale	2003	45	160

Flow regime

To improve the performance of constructed wetland as a wastewater treatment plant Bavor H. J. (2010) offers to change the flow regimes, for example, for agriculture and agroforestry runoff treatment design several individual wetland cells with different flow regimes. It means alternately using surface and subsurface wetlands. To make water move inconsistent with the natural terrain requires the use of forced pumping that means additional electricity consumption throughout the entire period of wetland use. Besides, treating municipal wastewater in the Latvian climate the cold season of the year should be taken into account. November till March the air temperature continuously is below 0^0C and creates a snow cover. Choosing surface flow constructed wetland for municipal wastewater treatment makes a risk of freezing that can impair the functioning of the wetland or stop it completely. Therefore, in the climate conditions of Latvia the municipal wastewater treatment is suitable in subsurface flow constructed wetlands.
In subsurface flow constructed wetlands (in horizontal or vertical direction) the wastewater is fed in at the inlet and flows slowly through the porous medium under the surface of the bed until it reaches the outlet zone where it is collected before leaving via level control arrangement at the outlet. As Vymazal (2008) presents during this passage the wastewater will come into contact with a network of aerobic, anoxic and anaerobic zones. In the aerobic zones roots and rhizomes occur that leak oxygen into the substrate (Vymazal, 2008). Wetland plants are morphologically and anatomically adapted to growing in a water saturated substrate by the presence of internal gas spaces called aerenchymas throughout the plant tissue. (Hondulas, 1994) Three constructed wetlands mentioned in Table 1 - Tervete, Birzi and Pedvale are all horizontal subsurface flow municipal wastewater treatment plants. The water flow direction is in a more or less horizontal path. Constructed wetland in Tinuzi is a vertical subsurface flow municipal wastewater treatment plant.

Determination of the area

The horizontal subsurface flow constructed wetlands for municipal wastewater treatment are installed with the calculation that water flow in the filter layer is directed horizontally 5 – 8 meters from the inlet infiltration pipes to the outlet drain pipes. Reeds on the top layer of the filter not only enrich the filter with oxygen, but also garnet the gravel and create an aesthetic view. The wetland area required for optimal wastewater treatment should be adopted 7 m^2 per PE. Wetlands can be successfully used in industrial wastewater treatment, assuming in calculations a PE equal to 60 g per day BOD_5. The optimal limit of BOD_5 at the inlet of constructed wetland is less than 150 mg/l. To get that limit, prior to inlet in wetland the effluent is treated mechanically 3 days in the septic tank. The wetland size depends on the time period, that wastewater is necessary to spend in wetland filter to purify to legal regulation requirements. The water subsistence time in the filter is around 7 - 8 hours, which provide wastewater treatment. The time is determined by the speed with which waste water flows through the filter. The filter material shall be selected from coarse sand or gravel with a particle size diameter 0.5 – 5 mm. The water flow speed v (m/s) through the filter is assumed 20 m per day or 0.00023 m/s. The distance L (m), that water makes from the inlet pipe to the drainage tube in time T (hours) is calculated by formula below.

$L = T * v = (7*3600) * 0.00023 = 5.8$ m.

In vertical subsurface flow constructed wetlands water filtrates through 1 m thick layer of coarse sand. The time of filtration is about 1 hour.

RESULTS AND DISCUSSION

As defined by Acharya G. (2005) wetlands have several advantages, like direct benefits: include the raw materials and physical products that are used directly for production, consumption, and sale including those providing energy, shelter, foods, water supply, transport, and recreation. Indirect benefits: these include ecological functions which maintain, protect, and support natural and human systems through services such as maintenance of water quality, flow and storage, flood control and storm protection, nutrient retention, and micro-climate stabilization, and other productive and consumptive activities. (Acharya, 2005)

A comparison was made between the two wastewater treatment plants mentioned above - aerotanks with forced aeration and subsurface flow constructed wetlands with the reed plantation on the surface of the filter. As the average capacity is presented 100 PE, that is approximately 15 m^3 per day.

As the main indicators, which compile the total operative costs of the wastewater treatment plant, equipment costs, construction costs, consumption of electricity during operation and maintenance are presented. These indicators are presented in Figure 1. In total costs the wastewater pumping station is not included, because the installation of it depends on the relief of the area. Besides the costs in both treatments plant kinds would be similar. Similarly the energy deletion well behind the pumping station is necessary in both cases.

The equipment costs of the aerotank comprise the cost of a metallic or polymer container with typical equipment that is usually offered by the company. The equipment also includes the air compressor and air inlet wheels. These equipment costs are mostly fixed and independent on the site conditions and location. Whereas the equipment costs of constructed wetland are variable, they vary depending on the filter material obtaining place distance, transport costs etc.

The construction costs as well as the equipment costs are lump sum payment when starting the operation of the treatment plant. Duration of the action and quality does not affect the costs. The companies that offer standard wastewater treatment plants with aeration are tended to include construction costs in the plant amount price or equipment costs.

In Figure 1 reflected construction costs are calculated according to the average offered construction costs in Latvia. Ground work and technique are taken into account.

The consumption of electricity during operation in Figure 1 is calculated according to the quantity of wastewater within 5 years.

Five years is a minimal warranty period for a wastewater treatment plant. Whereas the constructed wetland activity is required to meet the electricity, electric energy amount to be zero. Electricity consumption for the aerotank is drawn up of the air compressor.

The maintenance during the plant exploitation is complex to express in monetary. The more mechanical parts the equipment has the more necessary it is to closely monitor these facilities on regular basis, and it requires a specially educated person.

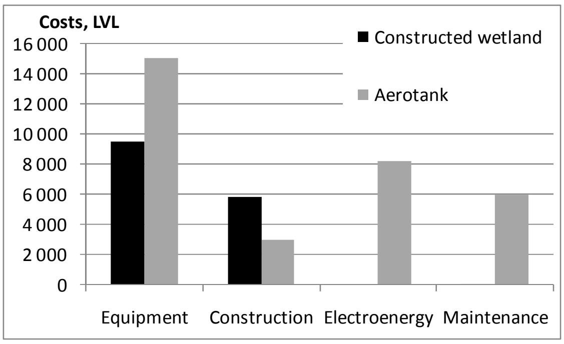

Figure 1. Cost comparison between constructed wetland and aerotank.

As Figure 1 shows constructed wetland has lower equipment costs than the biological treatment plant with aeration and activated sludge called aerotank. The occasion is non mechanical and natural materials are used as a filter to mineralize organic matter and nutrients with natural aeration. As the wetland takes greater area than a compact aerotank, also the construction draws up in higher costs. The wetland long-term operating costs are lower or even close to zero.

CONCLUSION

Latvian non-city residents are living in farmsteads as well as in the city outskirt areas where the occupied area of the property is sufficient to include open artificial or natural waters, such as a pond. Therefore, the installation of constructed wetlands is territorially suitable for Latvia.

In Latvia constructed wetlands are economically beneficial in small objects, i.e., separate households, villages up to 300 inhabitants, sanatoriums, because their operating costs are low.

Benefits of some wetlands will always be difficult to quantify and measure primarily because the required scientific, technical, or economic data are difficult to obtain and also that certain intrinsic values are not measurable by the existing economic valuation methods.

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