YYÜ TAR BİL DERG
(YYU J AGR SCI)
2017, 27(4): 651-656

Geliş tarihi (Received): 11.04.2017
Kabul tarihi (Accepted): 06.11.2017
doi: 10.29133/yyutbd.357070

Derleme/Review

Wastewater Treatment in Constructed Wetlands and Suggestions for the Use of Constructed Wetlands in Cold-Climate Regions

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Abstract: In recent years, the depleting water resources in response to the increasing need for water along with increase in population have led researchers to search new water resources. Among these sources, the most spectacular one is the use of polluted waters after treatment. One of the alternative methods for the treatment of wastewaters is constructed wetlands. This treatment mechanism is preferred due to its effectiveness in the removal of pollution and pathogen microorganisms as well as its economic contribution. Constructed wetlands are widely used in regions with warm climates, while in cold climate conditions, low temperatures result in decreased treatment efficiency. In this study, the use of constructed wetlands in cold climate conditions has been reviewed and necessary suggestions reported.

Key words: Cold climate, Construct wetlands, Wastewater, Wastewater treatment, Wastewater use

Yapay Sulak Alanlarında Atık Su Arıtımı ve Soğuk İklime Sahip Bölgelerde Kullanım Önerileri

Özet: Son yıllarda, nüfus artışıyla birlikte su ihtiyacındaki artışa karşın azalan su kaynakları, insanoğlunu yeni su kaynakları arayışına yöneltmektedir. Bu kaynaklar arasında da en göze çarpanı çeşitli yollarla kirletilmiş suları arıtarak kullanmaktır. Atık suyun arıtımı için alternatif yöntemlerden biri de yapay sulak alanlardır. Bu arıtım mekanizması ekonomik katkının yanında kirlilik ve patojen mikroorganizma gideriminde de etkili olmasından dolayı tercih edilmektedir. Yapay sulak alanlar ılıman ve sıcak iklime sahip yerleşim yerlerinde yaygın olarak kullanılmaktadır. Soğuk iklim koşullarında ise özellikle düşük sıcaklık nedeniyle arıtımın verimliliği düşmektedir. Bu çalışmada da soğuk iklim koşullarında kullanımı için yapılması gerekenler incelemiş ve öneriler verilmiştir.

Anahtar kelimeler: Soğuk iklim, Yapak sulak alanlar, Atık su, Atık su arıtımı, Atık su kullanımı

Introduction

Wastewater treatment by using low-cost ecotechnology has gained importance in recent years (Rana et al. 2011). Several alternatives are available for the treatment of water polluted by different uses. The treatment with constructed wetlands which are known as a natural and environmentally friendly system, applied using materials such as soil, plants, and gravels (Dan et al. 2011; Saeed and Sun 2012). Because of not used energy, it is also referred to as green treatment (Le et al. 2010; Bruch et al. 2011).

Uncontrolled discharge of domestic, industrial, and agricultural drainage water into the lakes, rivers, streams, and seas without proper treatment poses a threat to the nature and people in developing countries (Baylan 2016; Doğan Demir et al. 2016; Caselles-Osorio 2017). Wastewaters should be discharged into water resources after proper treatment to remove or minimize this threat (Çakmakcı et al. 2016). Due to the segregation economy for the treatment systems is difficult in the undeveloped countries, the treatment gains value in construct wetlands.

The number of constructed wetlands in Europe is over 50.000, while it is over 100.000 in North America and its use is becoming widespread in India, China, Hong Kong, South America with Norway which has a cold climate (Kadlec and Wallace 2009; İnci 2011; Vymazal 2011; Yan and Xu 2014). In addition, 30% of irrigation water in Australia is supplied from construct wetlands (Merz 2000).

In developed countries, the treatment of drainage water and waters such as industrial wastewaters, rainwater, and discharge waters from sugar refineries are performed using constructed wetlands (He et al. 2006; Bojcevska and Tonderski 2007; Ji et al. 2007; Manie et al. 2007; Li et al. 2009; Tang et al. 2009; Zhang et al. 2014). The treatment system which provides recycling of the water, also used for irrigation water in arid or semi-arid areas.

Constructed Wetlands

Constructed wetlands are used for treatment in many regions of the world since the 1950s and these systems are a lower-cost alternative to the available and relatively more expensive treatment systems (Verhoeven and Meuleman 1999; Scholz and Hwa Lee 2005; Poach et al. 2007). Because of easy installation and operation, constructed wetlands provide a financial advantage to developing countries (Konnerup 2009). Wastewater treatment with constructed wetlands is more favorable and practical than the classic methods (treatment plants) considering the requirement for electric energy in the operation, the high costs of maintenance and repair, and the need for qualified personnel in the operation of the treatment plants.

Surface flow systems and subsurface flow systems are widely used among the constructed wetland systems (Masi and Martinuzzi 2007; Garcia et al. 2010). Surface flow in constructed wetlands, the wastewater passes through the pretreatment unit containing the grid and reaches to the wastewater pond (covered with floating plants or plants at the bottom) and thus, the treatment is carried out under aerobic conditions. The subsurface flow systems carry out treatment under anaerobic conditions. The wastewater is passed through a filter and directly fed to the plant roots under a gravel bed (Vymazal 2009). The subsurface-flow with constructed wetlands are divided into two groups as horizontal and vertical flow systems and are prevalently used in countries such as Germany, Denmark, England (Cooper and Boon 1987; Masi and Martinuzzi 2007; Garcia et al. 2010). The vertical-flow systems which prevalently used in the European countries, produce higher oxygen the horizontal-flow systems and these systems are therefore preferred (Rousseau et al. 2004; Brix and Arias 2005; Cooper 2005; Kantawanichkul et al. 2009).

Advantages of Constructed Wetlands

The effective use of wastewater (in irrigation in arid and semiarid regions, golf courses, ornamental plants, and parks) are preferred to the lower cost of constructed wetland installation when compared to other treatment, not need for permanent personnel to operate the system, and their easy and fast maintenance and repair (Rousseau et al. 2004). The water treated with constructed wetlands reduces the inputs and increases the yield which is applied (Polprasert and Koottatep 2004; Shipin et al. 2005).

Disadvantages of Constructed Wetlands

Constructed wetlands usually have an economic life of fifteen years and have a lower treatment potential than that of treatment facility (Anonymous 2013). The quality of the treatment is affected by various factors, which include the climate (especially the temperature), chemical pollutants, industrial activities, and the socioeconomic characteristics of the region. Moreover, in cold-climate regions, the decrease in the treatment capacity in winter and the challenges in finding a suitable land for installation are also among the disadvantages of constructed wetlands.

Plant Species Used in Constructed Wetlands

The plants used in constructed wetlands serve as a depository of phosphorus, metals, and other elements (Kadlec et al. 1996). The plants commonly used in the treatment with constructed wetlands are bulrush, reeds, and cattail (*Typha latifolia*) and the trees commonly used in the treatment with constructed wetlands are alders (*Alnus glutinosa*), false indigo (*Amorpha fruticosa*), Aralia (*Aralia sieboldi*), and eucalyptus Gersberg et al. 1986; Breen 1990; Greenway and Bolton 1996; Zayed et al. 1998; Shutes 2001; Ye et al. 2001; Stoltz and Greger 2002; Leto et al. 2013; Vymazal 2013; Zhao et al. 2015; Wu et al. 2015). In Turkey, as a common reed (*Phragmites* spp.) and cold climate-resistant plant are used in majority of the constructed wetlands (Gökalp et al. 2013).

Use of Constructed Wetlands in Cold-Climate Regions

In regions with a cold, snowy, and frosty climate, microbial activities are reduced although the treatment continues (EPA 2000). Song et al. (2006) reported that meeting the biological oxygen demand (BOD_5) and chemical oxygen demand (COD) in spring and summer was more efficient than in autumn and winter. The same researchers reported that the removal of ammonia nitrogen and total phosphorus was more effective in summer

and autumn than that in spring and winter. Werker (2002), reported that the most of the constructed wetlands installed in Canada which had subsurface flow.

In cold-climate regions, since the water travels below the soil and therefore has a reduced contact with air, subsurface-flow treatment is preferred. Certain parameters are to be considered in the installation of constructed wetlands in regions with a cold climate. Some of these parameters are elaborated below.

Installation
The system should be built under the proper engineering conditions. The selected filling materials should be resistant to cold weather conditions. In cold regions, placing sand in the system will either impediment or prevent the freezing of water.

Location selection
Selecting a location is important in the installation of the system. Low-slope regions that are not a stream bed and not located in a flood or overflow site should be chosen (Gökalp and Çakmak 2015).

Plant selection
The vegetation has a delaying effect on the frost formation on the surface (Munoz 2006). The suitable plant type that can grow under the climate conditions of the region and is resistant to cold and frost should be selected. The plant should have high root development and a rapid cultivation period.

Water levels
In cold regions, freezing can be avoided by increasing the water levels while also taking the capacity of the system into account. Hershkowitz (1986), reported that water levels for constructed wetlands in summer were 10 cm, whereas they were 30 cm in winter in the Listowel region of Toronto (Canada).

Properties of the soil
A uniform topography with a gentle slope should be preferred for the wetlands. The slope should not exceed 5%, as high sloping land will also increase costs. (Metcalf and Eddy 2002). In addition, sandy soils should be preferred due to the high hydraulic conductivity.

Storage Requirements and pretreatment
Preentrance to the system, keeping or storing the untreated wastewater in stabilization ponds is recommended (Metcalf and Eddy 2002). Maintaining the treatment volume at 25%, increasing the circulation, and installing the outlet line at the bottom of the pond can also increase the effectiveness of the treatment (Angın et al. 2010).

Filling Materials
Filling materials serve as storage for many pollutants. The permeability of the material is among the important factors affecting the transport of water in the wetland.

Distribution System
For the controlled and efficient operation of constructed wetlands, the water should be fed to the system through different entry points.

Pipeline Layout
Installing the pipeline below the frost depth, covering the pipeline with sand and gravel, and increasing the slope of the pipeline (>1%) are recommended (Angın et al. 2010). PVC (Poly Vinyl Chloride) and Polyethylene pipes show a long-term resistance in wetlands and should therefore be preferred.

Isolation
Covering the water surface with cold-resistant plants and a mulch layer are minimized the energy loss by providing an additional heat isolation to the system (Smith et al. 1997; Wallace et al. 2001; Nivala et al. 2007).

Conclusion and Suggestions

The constructed wetlands with low costs of their installation and maintenance are the most suitable systems for domestic wastewater treatment in rural regions. The soil structure in the regions in which constructed wetlands will be established, should be examined and the soil studies should be performing tested. For a smoothly operating system, the input flow should be balanced and, if necessary, pre-treatment should be done and plants suitable for the regional climate should be chosen. Through treatment with constructed wetlands, pollution in

water resources and lands will be prevented, contagious diseases will be forestalled, and habitats will be provided for wild animals.

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