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Comparison of the treatment performances of blast furnace slag-based and gravel-based vertical flow wetlands operated identically for domestic wastewater treatment in Turkey

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Abstract

In 2001, to foster the practical development of constructed wetlands (CWs) used for domestic wastewater treatment in Turkey, vertical subsurface flow constructed wetlands (30 m^2 of each) were implemented on the campus of the METU, Ankara, Turkey. The main objective of the research was to quantify the effect of different filter media on the treatment performance of vertical flow wetlands in the prevailing climate of Ankara. Thus, a gravel-filled wetland and a blast furnace granulated iron slag-filled wetland were operated identically with primarily treated domestic wastewater (3 $m^3\ d^{-1}$) at a hydraulic loading rate of 0.100 $m\ d^{-1}$, intermittently. Both of the wetland cells were planted with *Phragmites australis*. According to the first year results, average removal efficiencies for the slag and gravel wetland cells were as follows: total suspended solids (TSS) (63% and 59%), chemical oxygen demand (COD) (47% and 44%), NH_4^+–N (88% and 53%), total nitrogen (TN) (44% and 39%), PO_4^{3-}-P (44% and 1%) and total phosphorus (TP) (45% and 4%). The treatment performances of the slag-filled wetland were better than that of the gravel-filled wetland in terms of removal of phosphorus and production of nitrate. Since this study was a pioneer for implementation of subsurface constructed wetlands in Turkey using local sources, it has proved that this eco-technology could also be used effectively for water quality enhancement in Turkey.

Keywords: Vertical flow constructed wetland; Domestic wastewater treatment; Nutrient removal; Gravel; Blast furnace granulated slag

1. Introduction

Being low-cost and low-technology systems, eco-technological approaches like "constructed wetlands" (CWs) are now standing as potential alternatives or sup-

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plementary systems for the treatment of municipal, industrial, agricultural wastewater, as well as stormwater (Moshiri, 1993; Kadlec and Brix, 1995; Kadlec and Knight, 1996; Cooper et al., 1996; Vymazal et al., 1998; Haberl, 1999; Kivaisi, 2001). Since the 1950s, throughout the world, constructed wetlands have been used effectively for several purposes with different configurations, scales and designs. This was because of their nutrient capturing capacity, simplicity, low construction/operation and maintenance cost, low energy demand, process stability, little excess sludge production, effectiveness and potential for creating biodiversity (Haberl, 1999).

Constructed wetland technology is more widespread in industrialized countries due to more stringent discharge standards, finance availability, change in tendency to use on-site technologies instead of centralized systems and to the existing pool of experience and knowledge based on science and practical work. Even though the potential for application of wetland technology in the developing world is enormous, the rate of adoption of wetlands technology for wastewater treatment in those countries has been slow (Kivaisi, 2001). Recently, as a result of the transfer of the knowledge, technical collaboration and co-operation by the developed countries, a variety of applications for CW technology for water quality improvement has also started to be implemented in developing countries like China, Kenya, Mexico, Nepal, Nicaragua, Tanzania, Uganda, India, Morocco, Iran, Thailand, and Egypt (Haberl, 1999; Kivaisi, 2001).

Similar to other developing countries, there is a great need for simpler, cheaper, and more reliable, effective and practical wastewater treatment alternatives in Turkey.

Therefore, implementing low-technology systems like constructed wetlands can also be appropriate solutions for treatment of different types of wastewater in Turkey. However, there have not been any full-scale constructed wetland applications for wastewater treatment in Turkey, until 2001 (Korkusuz et al., 2001). In this regard, to foster the practical development of constructed wetlands used for domestic wastewater treatment in Turkey, two parallel sets of the vertical subsurface flow pilot-scale constructed wetlands (30 m^2 each) with identical design configurations but with different filter media, were implemented on the campus of the Middle East Technical University (METU), Ankara, Turkey, in 2001. The design and implementation of the constructed wetlands were based solely on utilizing the local resources. The main objective of the research was to quantify the effect of different filter media (gravel and granulated blast furnace slag) on the treatment performance of vertical flow wetlands in the prevailing climate of Ankara.

In this paper, the first year removal performances of the identically operated gravel-based and blast furnace slag-based constructed wetlands of METU are presented. Total suspended solids (TSS), chemical oxygen demand (COD), total phosphorus (TP), *ortho*-phosphate phosphorus (PO_4^{3-}-P), ammonium-nitrogen (NH_4^+–N), nitrate-nitrogen (NO_3^-–N), and total nitrogen (TN) are compared to each other statistically and to the literature.

2. Materials and methods

2.1. Sizing of the constructed wetlands of METU

In 2001, two vertical subsurface flow constructed wetlands with dimensions of 4.5 m × 6.5 m × 0.60 m (W × L × D) and surface areas of 30 m^2, were implemented at the abandoned wastewater treatment plant at METU. The bottoms of the wetlands were lined with polyethylene of a thickness of 1 mm. A slope of 1% was created at the bottom of the wetlands to allow easier water collection. One of these wetlands was first filled with gravel (15 cm of 15/30 mm and 30 cm of 7/15 mm) from the bottom to the top and then with sand (15 cm of 0–3 mm). The other one was first filled with gravel (15 cm 15/30 mm), then with sieved blast furnace granulated slag (30 cm of 0–3 mm) that was provided from KARDEMIR Iron and Steel Company, Karabuk, Turkey, and finally with sand (15 cm of 0–3 mm) at the top layer. Several sizes of PVC pipes were used to distribute the wastewater flow evenly onto the vertical flow subsurface wetlands. Moreover, polyethylene drainflex pipes were used to collect the treated wastewater. The plan view of the constructed wetlands implemented on the campus of METU was illustrated in Fig. 1.

Constructed wetlands were planted with the shoots of the common reed (*Phragmites australis*), which were transferred from the natural reed beds on the campus, placed in the soil tubes and transplanted at a den-