SUBSURFACE FLOW CONSTRUCTED WETLAND FOR TREATMENT OF WASTEWATER OF SMALL COMMUNITIES IN TURKEY

[1]MERVE MAHMUTOGLU, [2]MUSTAFA SAIT YAZGAN

[1,2]Istanbul Technical University, Environmental Engineering Department, Istanbul, Turkey
E-mail: [1]mervemahmutoglu@gmail.com, [2]yazgan@itu.edu.tr

Abstract- Considering the wastewater treatment problems in small communities, it has been experienced that classical systems cannot be efficient and work in these places. The number of small communities in Turkey is about 100000 Thus, it can be said that wastewater treatment and infrastructures in small communities still remain as a big necessity in the country. The aim of this study is to inform about Subsurface Flow Wetlands (SFW) which is one of the most common methods of natural treatment and to evaluate the treatment efficiency of the system compared to Turkish Water Quality Standards. An area of 5250 m^2 is obtained by the selected parameters and calculations. This area might seem large, however, considering these systems are usually applied in suburban locations, it can be said that it is applicable in Turkey's conditions. As for the treatment efficiency, combined with the septic tank, it is known that the effluent quality of the constructed wetland meets the required Turkish Water Quality Standard, even in winter conditions.

Keywords- Natural treatment, Subsurface flow, Turkey, Wetlands.

I. INTRODUCTION

In big cities with large populations, there are clearly several wastewater sources (as shown in Figure 1). Therefore, it would be easy to predict the treatment of this wastewater would require infrastructure to collect it, treatment plants to meet the standards and all of this actions would be practiced with a low cost because of the large population.
However, small communities which only have domestic wastewater as a source have significantly smaller flowrates than cities as it is demonstrated in Figure 2. Thus, wastewater management in small communities must be handled in a different perspective.

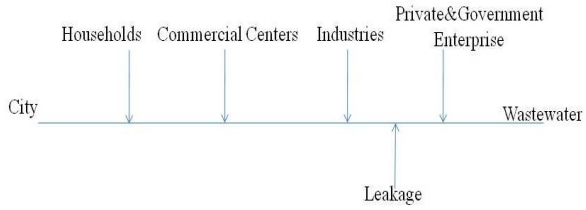


Fig.1. Wastewater Sources of Large Communities

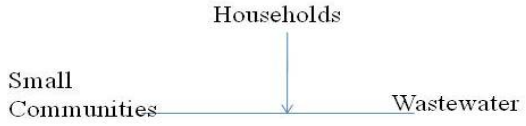


Fig.2. Wastewater Sources for Small Communities

The problems of the small communities' wastewater treatment can be listed as:

- High treatment cost per person compared to the cities
- Difficulties in collecting the wastewater
- Difficulties in meeting the required standards

Considering these problems and the locations of the small communities, it has been experienced that the regular infrastructure system used in cities would neither be efficient nor work in terms of construction and economics in these places for the following reasons,

- The small flowrate cannot prevent from solids accumulation (does not achieve the required velocity),
- The topography might be too slopped or too straight,
- The underground water level might be too close to the ground (leakage risk),
- The ground might have a low load capacity or be rocky,
- The population might be located dispersed (Kınacı&Yazgan, 2009).

The number of small communities in Turkey is more than 80000. This number goes up to 100000 when the treatment needs of the touristic areas are included. Thus, it can be said that wastewater treatment and infrastructures in small communities still remain as a big necessity in the country.
Wetlands may be described as transitional environments since they are spots between dry land and open water (if at the coast), around inland lakes and rivers, or as mires draped across the landscape. (Vymazal & Kröpfelová, 2008)

Wetlands used to be considered as neither fully terrestrial ecosystem nor fully aquatic ecosystems. They are not easily defined because they have a considerable range of hydrologic conditions and they own a great variation in terms of size, location, and human influences. Therefore, wetland definitions usually include three major components,
1. Wetlands are distinguished by the presence of water, either at the surface or within the root zone.

2. Wetlands often have unique soil conditions (hydric soils) that differ from adjacent uplands.
3. Wetlands support vegetation adapted to the wet conditions (hydrophytes) and, conversely, are characterized by an absence of flooding-intolerant vegetation (Maltby, 1986; Löffler, 1990; Sather et al., 1990; Larson, 1990; Whigham and Brinson, 1990; Tinner, 1999; Mitsch and Gosselink, 2000).

There are two types of wetlands; natural and constructed. Natural wetlands have been used for wastewater treatment for centuries. However, in the recent years, people have been concerned over the wetland losses which has created the idea of constructing the wetlands. These "constructed wetlands" are aimed to function as the natural wetlands and are intended to emulate the functions and values of natural wetlands that have been destroyed (Wetlands International, 2003).

Wetlands, either constructed or natural, offer a cheaper and low-cost alternative technology for wastewater treatment. Constructed wetland treatment systems are engineered systems that have been designed and constructed to utilize the natural processes involving wetland vegetation, soils, and their associated microbial media to assist the treatment of the wastewater. The system is based on the treatment of wastewater by filtration and through the vegetation grown on a specifically constructed bed. They are basically the same as the natural wetlands, however, designed in a way that the variables it consists can be controlled unlike natural wetlands (Mitsch and Gosselink, 2000, Vymazal & Kröpfelová, 2008).

As much as the treatment efficiency of the constructed wetlands is high, it requires some kind of pretreatment which is usually designed as a septic tank.

Constructed wetlands may take many forms. They are generally divided into two general categories;

- Free Water Surface Wetlands (FWS): The majority of water flow is over the sediment and through the above ground plant zone
- Subsurface Flow Wetlands (SFW): They are wetlands designed to conduct water through the bed of the system to make contact with the plant roots (Sherwood & oth., 1990) A typical SFW configuration is demonstrated in Figure 3.

In this paper, SFW are going to be in consideration and presented since it is a more common type used in the country. And wetland as one of the mostly used types of natural treatment systems are introduced and a SFW for a location with a population of 1000 is designed.

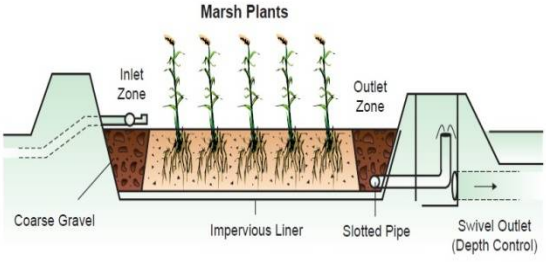


Fig.3. Typical SFW Configuration (Wetlands International, 2003)

The aim of this study is to inform about SFW which is one of the most common methods of natural treatment and to evaluate the treatment efficiency of the system compared to Turkish Water Quality Standards.

Within the scope of this thesis, it is focused on the advantages and disadvantages of the treatment system and design of a SFW systems.

II. DESIGN OF A SFW FOR A SMALL COMMUNITIES IN TURKEY

In this section, a constructed wetland design for a population of 1000 will be demonstrated. Pollutant loads, design parameters and the coefficient values are going to be selected either in typical ranges or according to the literature. As for temperature, the winter conditions are taken in consideration since winter has a higher flowrate and the area that will be obtained will be more secure.

2.1 Site Evaluation and Selection

It is the first step of designing and building of a constructed wetland. The characteristics of the land must be considered as they may become difficult or costly to correct later in the actual design and construction phases of the project (EPA, 2000). These characteristics include topography, soil characteristics, existing land use, flood hazard and climate of the area. (Metcalf-Eddy, 1991) As for the Subsurface Flow Wetlands, they require less space than Free Water Surface Wetlands and usually have a slope of 0 to 0,5 to percent (Crites & Tchobanoglus, 1998)

2.2 Population and Flowrates Estimations

Population of the hypothetical location for 2015 is 1000. The wetland project is designed for a 20 years period. Thus, the population for the year 2035 is calculated 1806 people.

Flowrate of the domestic wastewater is calculated as 253 m^3/d (q=20 l/d.P)

2.3 Septic Tank

The septic tank for pretreatment is designed and built rectangular shaped. Hydraulic retention time is selected as 1 day. The total volume of the tank is calculated by the equation of $Vt = \frac{3}{2} . Q.t$ and calculated as 380 m^3. Since the volume of wastewater is 253 m^3, Volume of sludge is found as 126 m^3. Depth of the tank is selected as 4 meters. Thus, the surface area ($A = \frac{Vt}{h}$) is calculated as $95\ m^2$.

Taking the ratio between the length and width as 3, width is calculated as 5.6 m and length is calculated as 16.8 m.

The dimensions (LxW) of the area is selected as 17x6 m respectively. If the septic tank volume is larger than 3-4 m^3, it is not constructed as one partition (Kınacı&Yazgan, 2009). Considering the dimensions, this septic tank may be divided into 3 parts.

2.4 Determination of the Design Parameters

The main design parameters for constructed wetland systems include hydraulic detention time , basin depth, basin geometry, BOD_5 loading rate and hydraulic loading rate. The ranges for some of the mentioned parameters are given in Table 1 (Metcalf-Eddy, 1991).

Table 1: Design Guideline for Constructed Wetlands

Design Parameter	Unit	Subsurface Flow System
Hyrdaulic Retention Time	d	4-15
Water depth	m	0,3- 0,8
BOD_5 loading rate	kg/ha.d	<66,5
Hydraulic loading rate	m^3/ha.d	150-500

2.5 Expected Treatment Efficiency by Regulation

According to Water Pollution Control Regulation legislated by the Ministry of Environment and Forestry, it is stated in Appendixes section, Table 21-5 (shown in Table 2) that the suspended solids concentration of the effluent of the constructed wetland is required to be below 200 mg/L for 2-hour composite sample and 150 mg/L for 24-hour composite sample. Considering the values calculated above, the SS concentration has already been reduced to a much lower value after the septic tank. Therefore, only BOD_5 is going to be considered as a design parameter (Sevi, 2006).

Table 2: Water Pollution Control Regulation Table 21.5 about Domestic Wastewater (For Municipal Treatment Plants that use biological treatment by Natural Treatment Systems (Constructed Wetlands))

Parameter	Unit	2-Hour Composite Sample	24-Hour Composite Sample
Biochemical Oxygen Demand (BOD_5)	mg/L	75	50
Chemical Oxygen Demand (COD)	mg/L	180	120
Suspended Solids (SS)	mg/L	200	150
Ph	-	6-9	6-9

2.6 Parameters for the wetland system

BOD_5 of influent is found as 208 mg/L. BOD_5 Effluent must be 50 mg/L according to Table 2.

The minimum removal efficiency needed is 0,76 (i.e.76% BOD removal). It is known that the BOD removal efficiency range of the constructed wetland is 80-99%. Thus, even the minimum efficiency of 80% would be enough to meet the standards.

The assumptions for the design of SFW system is given in Table 3.

Table 3: Assumptions for the design of SFW system

Season	Winter
Minimum wastewater temperature	6 ^{0}C
Slope of the land	0,02
Wetland depth	0,5 m
Filling material	10-12 mm river gravel
System Vegetation	Typha Latifolia
Porosity of the basin medium	0,42
Hydraulic Conductivity	1000 m^3/m^2.d (EPA
K_{20}	1,104 (EPA)

K_T Value for 6 ^{0}C and pore-space detention time (t') are calculated as $0{,}29\ d^{-1}$ and 4.9 days, respectively. Basin width (W) is calculated as 25,3 m and length (L) is found as 208,5 m.

2.7 Construction Steps of Constructed Wetland

The construction steps of a SFW is demonstrated in Figure 4 to Figure 11. The pictures belong to Eski Karaagaç Wastewater Treatment Plant in Bursa (Sevi, 2006).

RESULTS AND CONCLUSIONS

Natural treatment systems are easy to operate and economical treatment alternatives, specifically for the treatment of the domestic wastewater of small communities. They may be applied successfully in districts that have sufficiently large areas.

Wetlands, specifically speaking, constructed wetlands are one of the most common types of the natural treatment systems. Constructed wetlands are not only able to use their natural components like plants and soil in order to reduce the pollutants of the wastewater, but also allow these components to be kept under control which lets the treatment efficiency reach its possible maximum value. It is clear that constructed wetlands are a recently improving technology which also does not require a time and energy consuming and complicated technology.

As for the wetland types, SFW seem like more sufficient option compared to the free water surface wetlands. In addition to being more esthetical in terms of odor, insects etc. they have a faster response to the treatment. Therefore, SF is a more commonly applied process most of the time.



Fig.4. Construction Area Borders



Fig.5. Preparation of the construction site



Fig.6. Digging of the land



Fig.7. Land filled up with gravel



Fig.8. Septic tanks right by the wetland



Fig.9. Vegetation starting to grow (early stages of a wetland)



Fig.10. Typical appearance in summer conditions



Fig.11. Typical appearance in winter conditions

A SFW for the wastewater treatment of a population of 1000 has been designed within the context of this study. In all of the natural treatment systems, one of the first requirements is an available large area. Accordingly, an area of 5250 m2 is obtained by the selected parameters and calculations. This area might seem large, however, considering these systems are usually applied in suburban locations, it can be said that it is applicable in Turkey's conditions.

As for the treatment efficiency, combined with the septic tank, it is known that the effluent quality of the constructed wetland meets the required Turkish Water Quality Standard, even in winter conditions.

REFERENCES

[1]. Metcalf-Eddy, 1991, Wastewater Engineering-Natural Treatment System, pp. 992-995, Mc Graw Hill Press, New York.

[2]. Sevi, A., 2006, Bursa İli Harmancık İlçesi Evsel Nitelikli Atıksuların Dip Akışlı Yapay Sulak Alan Arıtma Sistemi ile Arıtılması, pp. 26, 27, Bursa.

[3]. Crites & Tchobanoglus, 1998, Small and Decentralized Wastewater Management Systems, pp. 599, 600, McGraw-Hill International Editions.

[4]. Sherwood C. Reed, 1990, Water Pollution Control Federation, Natural Systems For Wastewater Treatment, pp.1, 4, 5, Manuals of Practice for Water Pollution Control.

[5]. Smith, J. E., EPA, 1981, Process Design Manual For Land Treatment of Municipal Wastewater, pp. 1-4, 1-5, 1-10, 1-11, EPA.

[6]. Vymazal, J. And Kröpfelová, L., 2008, Wastewater Treatment in Constructed Wetlands with Horizontal Sub-Surface Flow, p. 210-217, Springer Science & Business Media.

[7]. Irvine Ranch Water District (IRWD), 2005, Natural Treatment Systems Design Guidelines, pp 25, 29.

[8]. Sherwood C. Reed, 1993, Subsurface Flow Constructed Wetlands for Wastewater Treatment A Technology Assessment, p. 2-1, EPA.

[9]. EPA, 2000, Constructed Wetlands Treatment of Municipal Wastewaters, p. 92, Cincinnati, Ohio

[10]. Kınacı, C. and Yazgan M., 2009, Land Treatment Course Notes, pp. 6, 12, 51, 52,67, 82, İstanbul

[11]. Wetlands International, 2003, The use of constructed wetlands for wastewater treatment, pp. 2, 6, 9, Malaysia Office

★★★