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# Assessment of Constructed Wetlands for Treatment of Domestic Wastewater in Small Communities: Konya City (Turkey) Experiences

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**Abstract:** Constructed wetlands (CWs) are artificial wastewater treatment systems consisting of shallow ponds, which have been planted with aquatic plants to treat wastewater. CWs are widely used for the treatment of domestic wastewaters of small communities in Turkey. Design, construction, operation and maintenance of constructed wetlands are important for the treatment of domestic wastewater. CWs that build in Turkey could not be operated efficiently due to making some faults about its project, construction and operation stage. In this study, design, construction and operation problems of 48 constructed wetlands in Konya city, Turkey, are evaluated.

***Keywords:*** *Constructed Wetlands, Wetlands, Wastewater Treatment, Wastewater*

## Introduction

Constructed Wetlands (CWs) are a natural, low-cost, eco-technological biological wastewater treatment technology designed to mimic processes found in natural wetland ecosystems, which is now standing as the potential alternative or supplementary systems for the treatment of wastewater (UN-HABITAT, 2008). CWs are an appropriate technology for small communities in rural and suburban areas. CWs are artificial wastewater treatment systems consisting of shallow ponds which have been planted with aquatic plants and which rely upon natural microbial, biological, physical and chemical processes to treat wastewater. A CW is a shallow basin filled with some sort of filter material (medium), usually sand or gravel, and planted with vegetation tolerant of saturated conditions. Wastewater is introduced into the basin and flows over the surface or through the substrate, and is discharged out of the basin through a structure which controls the depth of the wastewater in the wetland (UN-HABITAT, 2008). This system can be divided into two types, on one hand is free-water surface type (FWS) in which the water level is over the surface, and on the other hand is subsurface type (SF), in which the water level is maintained below the surface (Figure 1).

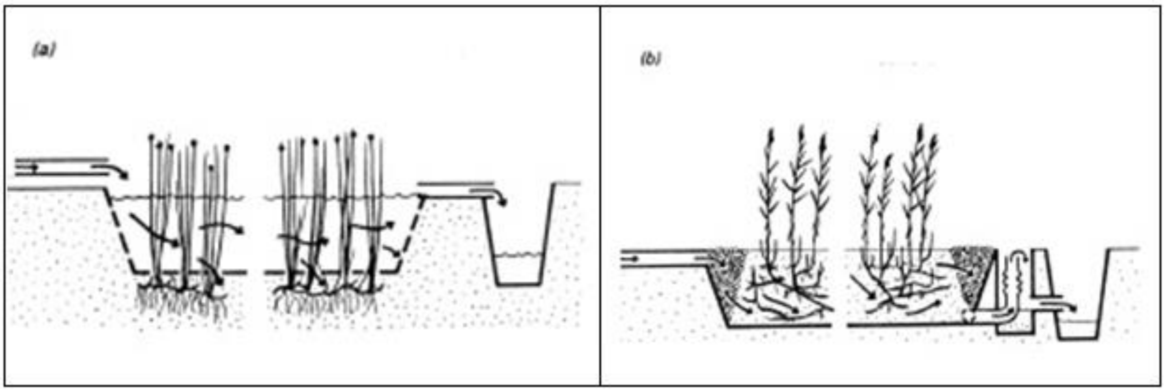


**Figure 1.** Schematic presenting each type of constructed wetlands which A: FWS, B: SF, (Brix, 1993)

A CW is a complex assemblage of wastewater, medium, vegetation and an array of microorganisms (most importantly bacteria). Vegetation plays a vital role in the wetlands as they provide surfaces and a suitable environment for microbial growth and filtration. Pollutants are removed within the wetlands by several complex physical, chemical and biological processes as shown in Table 1.

For the role of plants in constructed wetland, they contribute to nutrient transformation, offer mechanical resistance to flow, increase the retention time, facilitate settling of suspended particulates,

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and improve conductance of water through the media as the roots grow. The most frequently used plants species are *Scirpus sp.* (bulrush), *Typha sp.* (cattail), and *Pragmites communis* (reeds). Their typical characteristics are described in Table 2.


**Figure 2.** Photographs presenting each type of constructed wetlands in Turkey which A: Selcuk, Izmir (FWS), B: Hürriyet, Bursa (SF)

**Table 1.** Pollutant Removal Mechanisms in Constructed Wetlands (Cooper *et al*., 1996)

| Wastewater Constituents | Removal Mechanism |
|---|---|
| Suspended Solids | • Sedimentation<br>• Filtration |
| Soluble Organics | • Aerobic microbial degradation<br>• Anaerobic microbial degradation |
| Phosphorous | • Matrix sorption<br>• Plant uptake |
| Nitrogen | • Ammonification followed by microbial nitrification<br>• Denitrification<br>• Plant uptake<br>• Matrix adsorption<br>• Ammonia volatilization (Mostly in SF system) |
| Metals | • Adsorption and cation exchange<br>• Complexation<br>• Precipitation<br>• Plant uptake<br>• Microbial oxidation/reduction |
| Pathogens | • Sedimentation<br>• Filtration<br>• Natural die-off<br>• Predation<br>• UV irradiation (SF system)<br>• Excretion of antibiotics from roots of macrophytes |

Vegetation and its litter are necessary for successful performance of constructed wetlands and contribute aesthetically to the appearance. The vegetation to be planted in constructed wetlands should fulfill the following criteria:

- application of locally dominating macrophyte species;
- deep root penetration, strong rhizomes and massive fibrous root;
- considerable biomass or stem densities to achieve maximum translocation of water and assimilation of nutrients;
- maximum surface area for microbial populations;
- efficient oxygen transport into root zone to facilitate oxidation of reduced toxic metals and support a large rhizosphere.

**Table 2.** Typical characteristics of some plant species used in constructed wetland (Crites & Tchobanoglous, 1998; Reed *et al*., 1995).

| **Characteristics** | **Bulrush** | **Cattail** | **Reeds** |
|---|---|---|---|
| Distribution | Worldwide | Worldwide | Worldwide |
| Temperature, °C | 16-27 | 10-30 | 12-23 |
| pH range | 4-9 | 4-10 | 2-8 |
| Maximum salinity tolerance, ppt | 20 | 30 | 45 |
| Root penetration in gravel, m. | 0.6 | 0.4 | 0.3 |
| Habitat values | Seeds and rhizomes as a food source for several water birds, muskrat, nutria and fish | Seeds and roots as a food source for water birds, muskrat, nutria and beaver | Low food value for most birds and animals |
| Drought resistant | Moderate | Possible | High |
| Growth | Moderate to rapid | Rapid | Very rapid |

The removal mechanisms for nitrogen in constructed wetlands are manifold and include volatilization, ammonification, nitrification/denitrification, plant uptake and matrix adsorption. The major removal mechanism in most of the constructed wetlands is microbial nitrification/denitrification. Ammonia is oxidized to nitrate by nitrifying bacteria in aerobic zones. Nitrates are converted to dinitrogen gas by denitrifying bacteria in anoxic and anaerobic zones. The mechanisms for phosphorus removal in constructed wetlands are adsorption, complexion and precipitation, storage, plant uptake and biotic assimilation (Watson *et al*., 1989). Nutrient removal in constructed wetlands is summarized in Figure 3.

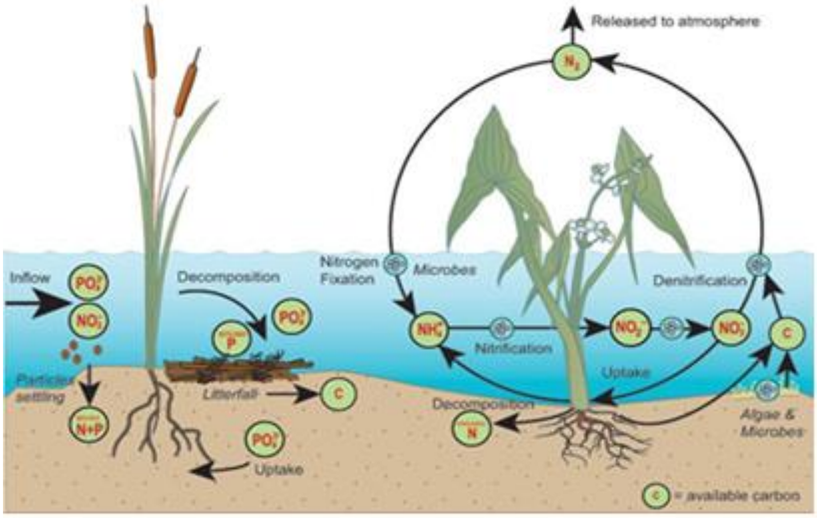


**Figure 3.** Nutrients removal in constructed wetlands

In recent years, septic tank designs have been developed to enhance removal efficiencies of solids and organic pollutants. The basic principle of such systems is to increase contact between the entering wastewater and the active biomass in the accumulated sludge. This is achieved by inserting baffles into the tank and forcing the wastewater to flow under and over the baffles as the wastewater passes from inlet to outlet. Wastewater flowing from bottom to top passes through the settled sludge and enables contact between wastewater and biomass.

## Materials and Methods

### Constructed Wetlands Application in Turkey

The use of CWs, especially for the treatment of domestic wastewaters of small settlements, is common in Turkey. According to Republic of Turkey the Ministry of Environment and Urbanisation, there are 260 artificial wetlands in Turkey. In addition, 1464 constructed wetlands were built by Directorate General of Local Administrations of the Ministry of Interior. Totally there are 1720 constructed wetlands in Turkey. These CWs serve 620.275 people in Turkey. According to Ministry of

Environment and Urbanisation in 2016, the population of Turkey is 65.025.536, which domestic wastewater ends with the wastewater treatment plant. Domestic wastewater of these population % 0,95 ends with CW.

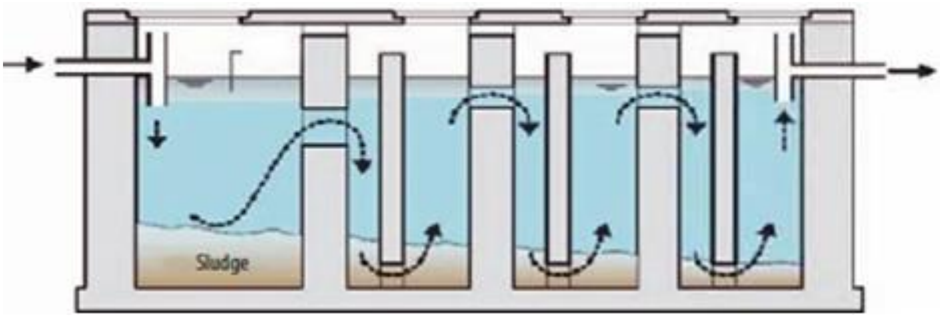


**Figure 4.** Schematic cross- section of an up flow septic tank

**Constructed Wetlands in Konya City**

There are 48 CWs in Konya as of year 2016. The town where the constructed wetlands are located and the population served by the CWs in Konya city are shown in Table 3. In this study evaluated CWs in Konya have septic tank and they are subsurface flow CW.

**Tablo 3**. CWs in Konya city

| Town | Neighbourhood/District | Plant Name | Population |
|---|---|---|---|
| Akşehir | Altuntaş | Altuntaş CW | 1882 |
| | Çakıllar | Çakıllar CW | 2646 |
| | Çamlı | Çamlı CW | 1049 |
| | Değirmenköy | Değirmenköy CW | 713 |
| | Karahüyük | Karahüyük CW | 1941 |
| | Yazla | Yazla CW | 1260 |
| Altınekin | Altınekin | Altınekin CW | 13941 |
| Beyşehir | Avdancık | Avdancık CW | 237 |
| | Bayafşar | Bayafşar CW | 708 |
| | Bayındır | Bayındır CW | 436 |
| | Karaali | Karaali CW | 2281 |
| | Karahisar | Karahisar CW | 286 |
| | Kurucuova | Kurucuova CW | 812 |
| Cihanbeyli | Günyüzü | Günyüzü CW | 1874 |
| Doğanhisar | Deştiğin | Deştiğin CW | 1087 |
| | Kemer | Kemer CW | 414 |
| | Konakkale | Konakkale CW | 579 |
| Halkapınar | İvriz | İvriz-1 CW<br>İvriz-2 CW | 4302 |
| Hüyük | Çavuş | Çavuş CW | 612 |
| | Göçeri | Göçeri CW | 472 |
| | Hüyük | Hüyük CW | 14719 |
| Ilgın | Avdan | Avdan CW | 260 |
| | Beykonak | Beykonak CW | 1177 |
| | Bulcuk | Bulcuk CW | 364 |
| | Büyükoba | Büyükoba CW | 329 |
| | Çavuşçugöl | Çavuşçugöl CW | 944 |
| | Çobankaya | Çobankaya CW | 219 |
| | Kapaklı | Kapaklı CW | 326 |
| Kadınhanı | Çavdar | Çavdar CW | 190 |
| | Kökez | Kökez CW | 403 |
| | Meydanlı | Meydanlı CW | 378 |
| Kulu | Yeşilyurt | Yeşilyurt CW | 800 |
| | Zincirlikuyu | Zincirlikuyu CW | 2079 |
| Meram | Bayat | Bayat CW | 225 |
| | İnlice | İnlice CW | 797 |

| | | | |
|---|---|---|---|
| | Karaağaç | Karaağaç CW | 161 |
| | Kızılören | Kızılören CW | 940 |
| | Sağlık | Sağlık CW | 551 |
| | Güvenç | Güvenç CW | 362 |
| Selçuklu | Meydan | Meydan CW | 201 |
| | Selahattin | Selahattin CW | 219 |
| | Sızma | Sızma CW | 2220 |
| | Gevrekli | Gevrekli CW | 1530 |
| Seydişehir | Gökçehüyük | Gökçehüyük CW | 334 |
| | Kuran | Kuran CW | 472 |
| Tuzlukçu | Erdoğdu | Erdoğdu CW | 294 |
| Yunak | Hacıömeroğlu | Hacıömeroğlu CW | 385 |

**Results and Discussion**

While common problems are encountered in the constructed wetlands in Konya, these problems are classified as project stage, construction stage and operation stage.

**Figure 5.** Clogging due to use unsuitable inlet and outlet structures

**Figure 6.** Clogging due to unsuitable media

**Project Stage**

- Wrong size land chosen due to incorrect population-flow rate calculations and mistakes in the predicted wastewater characterization.
- Die or not grown of vegetation due to unconsidered climatic conditions of district wrong calculation of amount CW plant.
- Animals such as sheep and cow entry to CWs for foraging because of absence wire fence
- Esthetics and health problems due to build CWs near to settlement.
- Not considering to access way to CWs.

**Construction Stage**

- Ground subsidence due to build septic tank with ignore soil properties,
- Clogging due to use unsuitable inlet and outlet pipe,
- Clogging due to use unsuitable inlet and outlet structures (Figure 5),

- Clogging due to use unsuitable media (Figure 6),
- Vegetation die or regional ponding due to unsuitable bed slope,
- Vegetation die due to choose wrong seed-time,
- Cannot control water depth in CW because of the unsuitable outlet structures.

**Operation Stage**

- Inadequate operation staff,
- Ignoring daily, monthly and yearly maintenance,
- Not pump out to septic tank (Figure 7),
- Not making plant harvest,
- Wrong set to water depth in CW,
- Not guard against clogging and weed.

**Figure 7.** Clogging septic tank

**Conclusions**

Due to low initial investment and operating costs, wastewater treatment using CWs is often preferred in small settlements in Turkey. However, existing CWs are not efficiently operated due to reasons such as projecting mistakes, unsuitable material selection, lack of regular maintenance, and lack of operating staff. It was determined that the plants were not planted and harvested in the right season. Because of this, plants are not found in most of the CWs. Besides, the effect of livestock activities in settlements was not considered. Despite all these negative experiences, CWs are an important alternative to wastewater treatment if it is correctly projected and operated.

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