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CONSTRUCTED WETLAND TECHNOLOGY FOR DOMESTIC WASTEWATER TREATMENT

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Abstract
Natural wetlands with various on-going complex physiological, chemical and biological processes in them, provide inherent self-treatment service of the nature. All these treatment processes are imitated in constructed wetlands. Constructed wetlands, so called as natural treatment systems, are widely used for treatment of domestic, industrial and agricultural wastewaters. The constructed wetland technology is composed of specially design basins filled with substrate filter materials and planted with aquatic species, inlet and outlet structures to regulate the flow regime within the basin and to remove various pollutants from the wastewaters. In case relevant criteria were not taken into consideration in design, operation, maintenance and monitoring of these systems, irremediable or irreversible failures are evident. Therefore, national and international standards, influent wastewater characteristics, site geography and climate conditions should be considered in design, constructions should be carried out precisely and operation-maintenance-monitoring activities should also be followed to meet the desired performance expectations. In this study, use of constructed wetland technology in domestic wastewater treatment was explained and potential mistakes made in design and operation of these systems was pointed out.

Keywords: Constructed wetland, domestic wastewater, treatment, Wetland.

1. INTRODUCTION

Just because of ever-increasing world population, water demands are also continuously increasing. Therefore, there is an ever-aggravating competition among agricultural, domestic and industrial water users for limited and depleting fresh water resources. Continuously polluted waters, decreasing water resources due to global warming and climate chance, increasing labor and energy costs all brought the water and treatment technologies into the first place of the world's agenda. To overcome the water-related problems, water losses in agricultural, domestic and industrial uses should be prevented, effective and efficient water use should be provided and possible use of wastewater and treated water should be investigated.

As it was in various parts of the world, wastewaters are mostly discharged into seas, rivers and other water bodies due to high treatment costs in Turkey. About 2400 of 3225 municipalities have a sewage system and of 3.26 billion m^3 wastewater 44.7% is discharged into sea, 43.1% into rivers, 3.5% into dams, 2.1% into lakes, 1.5% into lands and 5.1% into other receiving bodies. About 69% of discharged wastewater is treated with 236 treatment facilities serving to 442 municipalities. Of these treatment facilities, 29 are physical, 158 are biological, 32 are advanced and 17 are natural treatment facilities (Anonymous, 2010).

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Natural treatment systems, so called as constructed wetlands, are employed as an alternative to conventional treatment systems because of their low construction, operation and maintenance costs, low energy demands, simple operation and low sludge generation (Knight et al., 1987; Kadlec and Knight, 1996). These systems are specially designed systems imitating the natural wetlands and include soil, plant and microorganisms to remove the pollutants from wastewaters. An excavated constructed wetland basin is lined with compacted clay or synthetic membrane and filled with graded sand-gravel substrate (Anonymous, 2011). Today, constructed wetlands are widely used to treat domestic wastewaters (Cooper et al., 1997), agricultural wastewaters (Rivera et al., 1997), industrial wastewater and runoff waters (Dombush, 1989).

Constructed wetlands are mostly used for sewage treatment of villages in Turkey. Natural treatment systems are defined as the "primary treatment alternative" in rural development strategy document of State Planning Organization of Turkey. In present study, possible use of constructed wetlands for wastewater treatment in rural parts of Turkey, especially in villages, were investigated. Possible use of treated water in irrigation was evaluated and current drawbacks observed in construction, operation and maintenance of these systems were also put forward in this study.

2. WETLANDS IN NATURE

A natural wetland is defined as the transition zones between lands and water bodies and represent the sites with specific flora and fauna adapted to these regions and characterized with their high water tables and high organic matter contents (Çiftçi et al., 2007) (Figure 1). They usually have water depths less than 6 meters and include the sites of flood plains, shallow shores, lagoons, estuaries, sluggish sections of rivers, lakes with fresh, bitter or salt water (Cirik, 1993). Nutrient inflow to wetlands supports the growth of vegetation and such vegetation constitute the primary component of wetland food-chain and converts inorganic materials into organic materials (Hammer and Bastain, 1989). Wetlands are the natural heritages of the world with their biologic diversity and provide the several functions (Ayvaz, 2005). They stabilize the water regimes of the regions where they are located through charging or discharging groundwater tables, storing floodwater, controlling floods, preventing see water intrusion; raise the humidity of the region where they are located and have positive impacts primarily on local climate parameters such as precipitation and temperature; purify waters through retaining residues and poisonous materials or using nutrients; they are the ecosystems with the highest biological production like tropical rainforests; they provide a habitat for a rich flora and fauna; finally they have a high economic value with their supports provided in fishery, agriculture, livestock, reed production and tourism.

Figure 1. Natural wetland images (Source: https://landsat.gsfc.nasa.gov/where-the-wetlands-are/)

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Water treatment functions of natural wetlands bring the preservation of such sites into consideration. Although researches indicated high wastewater treatment performance of natural wetlands (Knight et al., 1987; Kadlec and Knight, 1996), such implementations may have some adverse effects with regard to preservation of these sites. Toxic elements in wastewaters, negative impacts of pathogens and additional hydraulic loading and nutrients can cause long-term degradations in these natural systems. Therefore, constructed wetland technologies have been developed instead of natural ones for wastewater treatment purposes.

3. MAN-MADE ARTIFICIAL WETLANDS (CONSTRUCTED WETLANDS)

Man-made artificial treatment systems imitate the natural systems and contain plant, soil and microorganisms, commonly encountered in natural ones, within specially-designed and constructed basins to remove pollutants from wastewaters (EPA, 1993) (Figure 2). These systems are commonly composed of a compacted clay or synthetic liner overlaid with graded sand and gravel substrate material, reeds like aquatic plants and the other engineering structures adjusting hydraulic loading rates, retention times and water levels within the basin. Constructed wetlands, also called natural treatments systems, today are used for treatment of various wastewater resources.

Constructed wetlands have various advantages over the conventional treatment systems. They are cheaper and easier to construct, require low energy and operational costs, do not require expert personnel, environment-compatible systems and provide habitat for various wetland organisms. Beside these advantages, they have also some disadvantages. They require larger areas and system performance is less stable and easily be altered by changing climate conditions (EPA, 1995).

Constructed wetlands are primary classified as surface flow and sub-surface flow constructed wetlands. A successful constructed wetland design should take the following general criteria into consideration (EPA, 1995):

- The design should be kept as simple as possible and complex technological approaches should be avoided to prevent possible failures.
- The design should be so performed as to require the least maintenance.
- The wastewater flow should be supplied through gravitational flow.
- Extreme weather and climate conditions should be considered in design.
- The design should comply with the natural landscape and topography.
- The systems should be allowed time to reach the desired performance values.

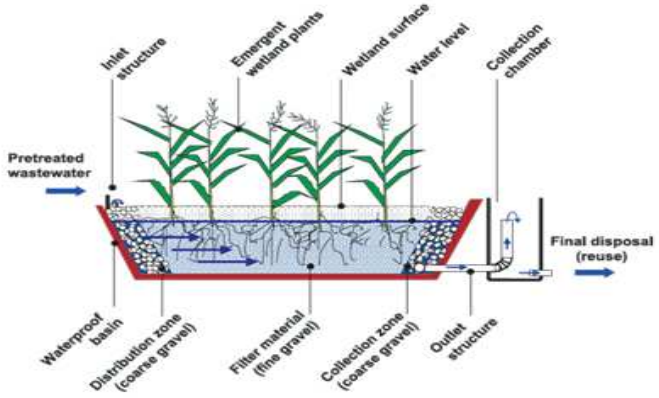

Figure 2. Components of a constructed wetland (Source: http://www.theadvocateproject.eu/blog/constructed-wetlands-a-promising-system/)

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Surface-flow constructed wetlands

Surface flow constructed wetland systems are typically composed of a bed or canal, a compacted impervious layer, soil or another media for plant rooting and relatively low water level flowing through the system (Figure 3). Water surface is above the filtrate or fill material. These systems resemble the natural wetlands and provide various benefits for wild life beside water treatment (Shutes et al., 2002). While the sections closer to surface are aerobic, deeper sections and substrate material are anaerobic. The primary advantage of these systems are their low investment, operation and maintenance costs, easy construction and operation and the basic disadvantage is the land requirement to construct such systems since they require significantly larger areas than the other constructed wetland or conventional treatment systems. In system design, biological oxygen demand (BOD), total suspended solids (TSS), nitrogen (total Kjeldahl nitrogen, dinitrification and ammonium nitrogen), phosphorus, coliform bacteria, metal and other particulate pollutant performances are taken into consideration.

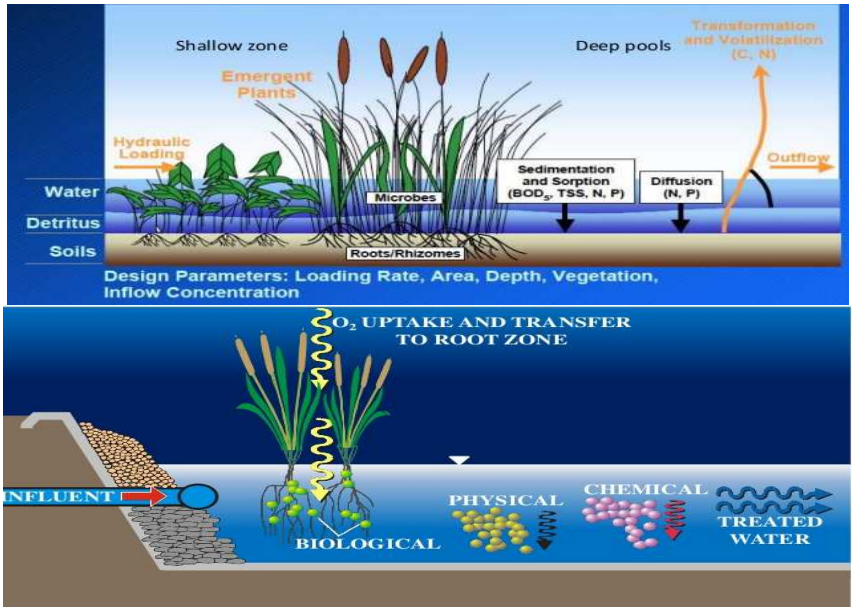

Figure 3. Surface-flow constructed wetlands (Source: https://www.slideshare.net/oceanexchange/constructed-wetlantds)

Sub-surface flow constructed wetlands

Subsurface flow constructed wetlands are composed of a compacted clay or synthetic impermeable liner overlaid by graded gravel and sand substrate material planted with aquatic plants and water level control structures (Figure 4). They are designed in either horizontal flow or vertical flow and can be used with and without emergent plants (Young, 2000; George, 2000; Liehr, 2000). Contrary to surface flow systems, water does not come out to surface in these systems and flows through a substrate material and reaches to outlet (EPA, 1999).

The most significant component of these systems is the substrate material filtering the wastewater. The material both provides a medium for rooting of aquatic plants and distributes influent, directs and collects effluent, provides surface area for microbial activity and filters suspended solids. Although various size and composition of substrate materials have been tried, there are not any concrete evidences about which size or type of material is the best. The basic criterion is not to allow small particles settle into the pores of coarser ones. Substrate upper surface should be leveled and about 1% slope should be provided at bottom surface. Inlet pipes should be so arranged to

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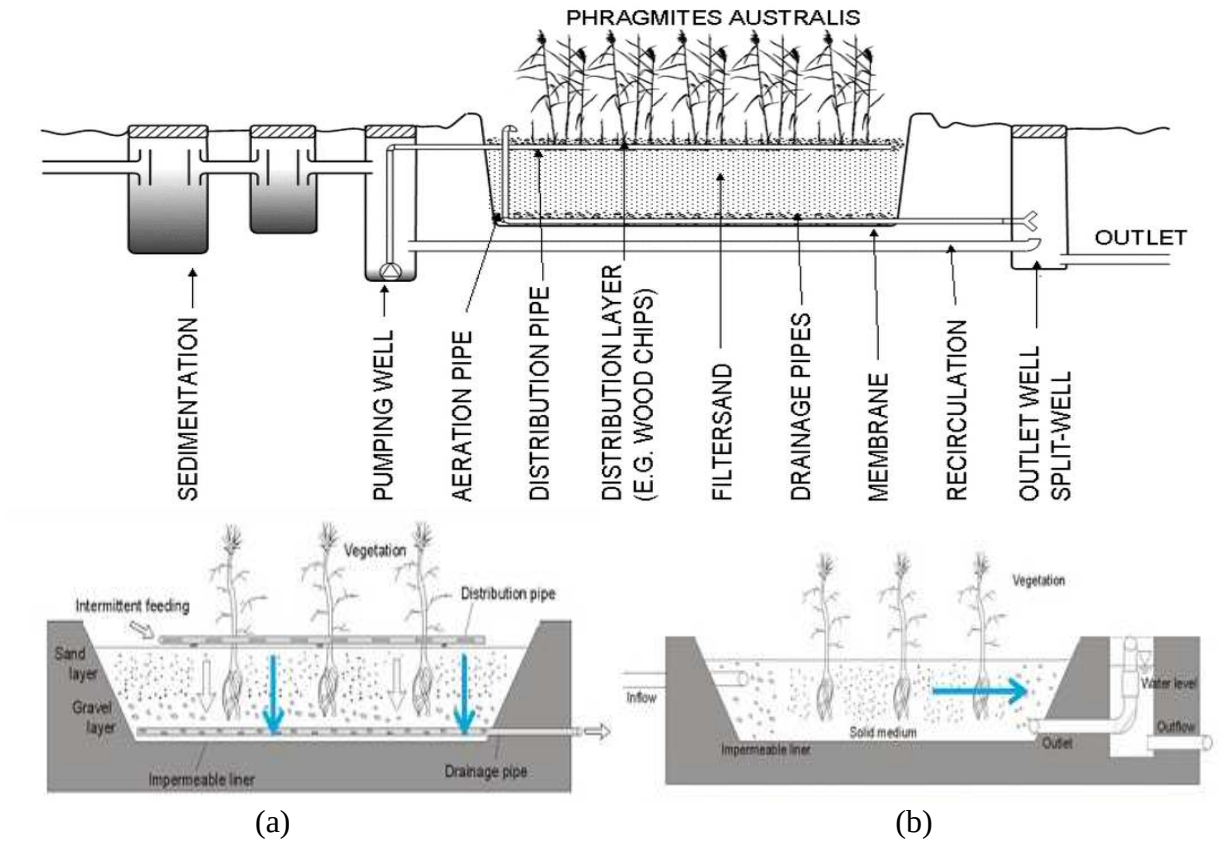
prevent short-circuit and substrate clogging and provide an equal flow. Outlet pipes should also prevent short-circuits, provide equal water collection and allow the operators to arrange the water level and effluent drainage.



(a) (b)

Figure 4. Sub-surface-flow constructed wetlands (a) Horizontal flow, (b) Vertical flow (Source: https://www.pc-progress.com/en/Default.aspx?h3d2-Wetland)

4. PROBLEMS ENCOUNTERED IN CONSTRUCTED WETLANDS

In Turkey, sub-surface horizontal flow constructed wetlands are commonly used for domestic wastewater treatment in rural parts, especially in villages. Usually the type-projects designed by Special Provincial Administrations just by taking the total population to be served into consideration are implemented. Most of the time, local conditions, influent quality parameters, hydraulic loading rates, retention times and site-specific characteristics are not taken into consideration. Therefore, various failures occur because of such design errors and most of the already constructed systems are not either well-operating or not-operating at all (Gokalp et al., 2014).

The common failures are classified as: failures in site selection, inlet clogging, substrate clogging and consequent water poundings over the surface, outlet clogging, leakage through slopes, plantation failures, failures in operation and maintenance. Effluents of properly operating systems can also be used for irrigation purposes. However, irrigation water quality parameters should definitely be taken into consideration before using treated effluents Plant uptake, substrate adsorption, precipitation and complexation are the primary phosphorus removal mechanism in constructed wetlands. Adsorption over substrate surfaces is the primary phosphorus removal mechanism in vegetated beds. Physical and chemical conditions, wastewater characteristics, plant

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roots, characteristics of substrate materials and wetland microorganisms greatly influence adsorption process of pollutants.

5. CONCLUSION AND RECOMMENDATIONS

When the treated effluents were reached to aquatic environments, they may result in eutrophication if they were not sufficiently treated for phosphorus removal. Therefore, required discharge criteria should definitely be met both in conventional and natural treatment systems. For phosphorus removal, while various chemicals are used in conventional treatment systems, mainly substrate materials are employed in constructed wetlands. Surface characteristics, porous nature and chemical composition of substrate materials greatly influence their phosphorus removal capacities. Generally sand, gravel, pumice and zeolite-like natural aggregates, amended zeolite-like processed minerals and fly ash and slug-like industrial waste materials are used as the common substrate materials in constructed wetlands. These substrate materials used either alone or in mixtures with sand-gravel. Further research is recommended about different mixture ratios, other waste materials and their surface characteristics for phosphorus removal.

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