Efficiency of a natural wetland for effluent polishing of a septic tank

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ABSTRACT
Wetlands now days apply as a polishing system for the classical wastewater treatment, in addition of different usages. Usually wetland systems are inexpensive methods vs. expensive high technology treatment systems. Objective of this study is an evaluation of natural wetland treatment in polishing of a septic effluent. Research duration works extended for 10 months on a natural wetland system in Pardis of Mazandaran University of medical sciences and eastern north of health faculty. Wastewater quality index such as pH, EC, BOD, COD, TSS, Nitrate, Phosphorus, Ammonia and Temperature performed on the samples of influent and effluent of the system. The study showed the system works as a buffering system for flow and pH. Results indicated that average of BOD_5 and TSS efficiency were 67.70and 83%, respectively. Efficiency of COD was 65.26 and 80 % for a Low and moderate strength influent respectively. Average of phosphorus, NH_3 and Nitrate in effluent were 0.032 mg/L, 7.18 and 0.036 mg/L, respectively. Efficiency of ammonia and Phosphorus were slightly increased in best condition. Based on this study result, natural wetland can be success in BOD, COD, and TSS removal of the classical septic tank, but for nitrogen and Phosphorus removal do not have considerable effects.

Key words: Natural wetland; septic tank effluent; efficiency

INTRODUCTION
Wetlands define as transitional environments, that they lie between dry land and open water at the coast, around inland lakes and rivers, or as mires draped across the landscape. In some texts, wetlands are intermediate between terrestrial and aquatic ecosystems [1]. Wetlands are characterized by unique hydrologic, soil (substrate), and biotic conditions. Wetland substrates are called hydric soils, meaning they are saturated with water for part or all the year. Saturated soils become anaerobic (without oxygen) as water stimulates the growth of micro-organisms, which use up the oxygen in the spaces between soil particles. When soils become anaerobic, they change significantly in structure and chemistry. These factors all make wetland soils stressful to terrestrial plants [2]. Natural wetlands are ecosystems that occur in areas that are intermediate between uplands and deep-water aquatic systems. Technical and regulatory definitions of wetlands focus on the dependence of wetland ecosystems on shallow water conditions which result in saturated soils, low dissolved oxygen (DO) levels or anaerobiosis in soils, and colonization by adapted plant and animal communities [3, 4]. The ability of wetland ecosystems to improve water quality naturally has been recognized for more than 30 years [5, 6].

Natural wetlands have probably been used for wastewater disposal for as long as wastewater has been collected, with documented discharges dating back to 1912. Natural wetlands have been used for wastewater treatment for centuries. Natural wetlands are still used for wastewater treatment under controlled conditions [7]. Treatment wetlands bridge the gap between “hard engineering” and natural science.

Water supply and control (recharge of groundwater aquifers, drinking water, irrigation, flood control, water quality and wastewater treatment), erosion control, gene pools and diversity, energy (hydroelectric, solar energy, heat pumps, gas, solid and liquid fuel), use of plants (staple food plants, grazing land, timber, paper production, roofing, agriculture, horticulture, fertilizers, fodder), wildlife (e.g. breeding grounds for water flow, preservation of flora and fauna), fish and invertebrates (shrimps, crabs, oysters, clams, mussels), mining (peat, sand, gravel), integrated systems and aquaculture (e.g. fish cultivation combined with rice production), education and training, recreation and reclamation are some aspects of wetlands [8, 9] . While most of natural wetland systems were not designed for wastewater treatment, studies have led to both a greater understanding of the potential of natural wetland ecosystems for pollutant assimilation and the design of new natural water treatment systems [10]. It is well documented that aquatic and wetland macrophytes release oxygen from roots into the rhizosphere and that this release influences the biogeochemical cycles in the sediments through the effects on the redox status of the soils and sediments [11]. Wetland plants attempt to minimize their oxygen losses to the rhizosphere. Wetland plants do, however, leak oxygen from their roots [2]. Rates of oxygen leakage are generally highest in the sub-apical region of roots and decrease with distance from the root-apex [12]. Wetland plants conserve internal oxygen because of suberized and lignified layers in the hypodermis and outer cortex [13].

Using different assumptions of root oxygen release rates, root dimensions, numbers, permeability, etc., [14] calculated a possible oxygen flux from roots of *Phragmites australis* up to 4.3 g m^{-2} d^{-1}. Others, using different techniques, have estimated root oxygen release rates from *Phragmites* to be 0.02 g m^{-2} d^{-1} [5, 15, 16], 1-2 g m-2 d^{-1} [17] and 5-12 g m^{-2} d^{-1}[18]. However, most of this oxygen is probably used to cover the respiratory demand of the root-rhizome system leaving only insignificant amounts of oxygen available for waste treatment processes [2].

Macrophyte growth is not the only potential biological assimilation process: microorganisms and algae also utilize nitrogen. Ammonia is readily incorporated into amino acids by many autotrophs and microbial heterotrophs [1]. Nitrogen can be absorbed by plants in three distinct forms: nitrate, ammonium and amino acids. Nitrate must be first reduced to ammonium, which must be then attached to a carbon skeleton before it can be used in biosynthesis. Plant species differ in their preferred forms of nitrogen absorbed, depending on the forms available in the soil [19- 20]. Most plants, however, are capable of absorbing any form of soluble nitrogen, especially if acclimated to its presence. Nutrients are assimilated from the sediments by emergent and rooted floating-leaved macrophytes, and from the water in the free-floating macrophytes [21]. Nitrogen is taken up and assimilated by growing plants throughout the growing season. However, uptake rate varies widely during the growing season.

Phosphorus that enters the wetland water column is rapidly absorbed by bacteria, periphyton, and plants. Radioisotope P studies have shown that 10 to 20% of the P is controlled by the biotic uptake initially [22]. Inorganic phosphorus transformations, subsequent complexes, and P retention in wetland soils and sediments are controlled by the interaction of redox potential, pH values, Fe, Al, and Ca minerals, organo-metallic complexes, organic matter content, clay minerals, hydraulic loading, and the amount of native soil P [1, 22]. Humic substances can act as bridges between humic macromolecules and phosphate ions.

Use of wetlands (both natural and constructed) as biological treatment systems for effluent purification has developed rapidly over the last 30 years with the increasing scientific documentation of the role of plants in wastewater purification [23, 24]. The growing interest in wetland systems is in part due to the recognition that natural treatment systems offer advantages over conventional concrete-and-steel, equipment-intensive, mechanical treatment plants. When the same biochemical and physical processes occur in a more natural environment instead of reactor tanks and basins, the wetland system often consumes less energy, is more reliable, requires less operation and maintenance and, as a result, costs less Most research on the use of wetlands for wastewater treatment has been directed towards using municipal wastewaters to reduce the concentrations of nitrogen and phosphorus and to lower the biological oxygen demand [25, 26]. Oxygen consumption rates in treatment wetlands are most commonly inferred from water quality data [27].

Wastewater polishing systems utilizing wetland plants have proven to be very reliable. Wetland plants create an environment that supports a wide range of physical, chemical, and microbial processes. These processes separately and in combination remove total suspended solids (TSS), reduce the influent biochemical oxygen demand (BOD), transform nitrogen species, provide storage for metals, cycle phosphorus, and attenuate organisms of public health significance. The biogeochemical cycling of macro and micronutrients within the wetland is the framework for the treatment capability of a wetland system. Objective of this study is an evaluation of natural wetland treatment in polishing of a septic effluent.

MATERIALS AND METHODS

This study performed on a septic effluent polishing natural wetland at eastern north of health faculty in Pardis of Mazandaran University of Medical Sciences, km 18 khazarabad road in Sari city, north of Iran. Dimension was 0.9 m mean wide and 11.45 m long and 0.40 m mean dept. Natural plants growth in this natural system was Phragmites austruiis. The density of Phragmites austruiis plant was 50-100 m^{-2}. Research duration works extended for 10 months. Measurements were made of pH, EC, BOD_5, COD, TSS, Nitrate, Phosphorus, Ammonia and Temperature. Sampling was carried out by collecting samples from influent and effluent of the system. All analytical measurements were done in accordance with the 20th edition of Standard Methods [28]. The natural wetland system displayed in Fig. 1 and 2. Fig. 3 shows the flow diagram of the system.

Fig.1: Septic effluent polishing natural wetland in research site.

Fig.2: Septic effluent pipe entering to polishing natural wetland in the research site

In this research, too much grab and composite samples had taken in different condition, hydraulic and organic loading from inlet, middle and effluent of the system for analysis.

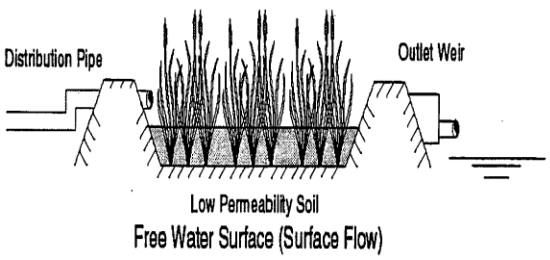

Fig.3: Septic effluent pipe entering to polishing natural wetland in the research site

RESULTS AND DISCUSSION

Fig. 4 illustrates the optimum detention time resulting from the natural wetland polishing system by NaCl tracing method for high flow rate. The results indicate that optimum detention time of the system was 4 hours for high flow rate, while this detention time for low flow rate was 3.2 days.

The results indicate that influent wastewater had a low to moderate level of COD (between 100-400 mg /L). BOD_5 efficiency ranged from 54.19 to 79.2 percent, with an average 65.12% for a Low strength Influent and cold season, while this efficiency increased to 67.7% for a moderate strength Influent and higher temperature (Fig. 5). Low strength Influent BOD_5 ranged from 86.5 to 193.8 mg/L, with an average influent of 130.8 mg/L, while the effluent ranged from 32 to 58.4 mg/L, with an average effluent of 43.76 mg/L (Fig. 6).

Moderate strength Influent COD ranged from 240 to 384 mg/L, with an average influent of 301.9 mg/L, while the effluent ranged from 48 to 164 mg/L, with an average effluent of 120.25 mg/L. Fig.5-7 and Fig.12 show the concentration of COD in the treated effluent, were all within the upper limits set for municipal wastewater discharge to agricultural water in Iran [29]. COD efficiency ranged from 40.44 to 80.00 percent, with an average 60.49%. Also efficiency of COD was 65.26% for a Low strength Influent and cold temperature, while this efficiency increased to 80% for a moderate strength Influent and higher temperature. This results show that when temperature, macrophytes growth and strength of influent were increased, efficiency of BOD_5 and COD will increase.

Low strength Influent COD ranged from 104 to 208 mg/L, with an average influent of 166 mg/L, while the effluent ranged from 34 to 84 mg/L, with an average effluent of 57.12 mg/L. Fig. 6 and Fig. 11 shows the concentration of COD in the treated effluent, were all within the upper limits set for municipal wastewater discharge to surface water in Iran [29]. COD efficiency ranged from 58.75 to 80.68 percent, with an average 65.26%.

Moderate strength Influent BOD_5 ranged from 126 to 274 mg/L, with an average influent of 205 mg/L, while the effluent ranged from 43 to 86 mg/L, with an average effluent of 65.37 mg/L (Fig. 6-8). BOD_5 efficiency ranged from 57.39 to 77.56 percent, with an average 67.70%.

The data presented in Fig. 6, Fig. 12 and Fig.14 show the concentrations of COD and BOD_5 in the treated effluent of low strength wastewater, were all within the upper limits set for municipal wastewater discharge to surface water in Iran [29]. But the data presented in Fig. 5, Fig. 8 and Fig.13 show the concentration of COD in the treated effluent of moderate strength wastewater, were all within the upper limits set for municipal wastewater discharge to agricultural water in Iran [29].

The Fig. 9 indicate that the temperature range of influent in warm condition were 18.5 -21.5 °c and for effluent 17.5 -19.5 °c). The temperature range of influent in cold condition ranged from 8.6 to 17.1°C with an average of 14.2°C, while the temperature range of effluent was 9 to 15.6°C with an average of 12.5°C.

The data presented in Fig. 10 show the EC in raw and the treated effluent were reduced from 8 AM to 12 and was significantly increased from 12 to 15. These changes can be due to the washing and consumption type of consumers and restaurant activities.

The Fig. 11 shows pH range of influent was 7.85 to 8.86 with an average of 8.2 and for effluent changed to 8.16 to 8.81 with an average of 8.37. Also the present findings seem to be consistent with other research, [30, 31] which found the macrophyte wetland system works as a buffering system vs. pH fluctuations. Often pH of the influent increased but system persists for PH changes in effluent. Usually PH of the effluent was in the neutral range. Buffer capacity of the system was increased with increasing of active biomass. Also the results indicate that pH had a rather reducing when temperature were increased.

Efficiency of NH_4-N removal and convert it to NO_3-N affected by temperature and macrophyte growth. The Fig. 15 shows the temperature effect on the NH_3-N removal. Usually in optimum condition temperature was a rather higher converting of NH_4-N to NO_3-N and it's absorption by macrophyte was higher, but the result in cold condition indicate that level of NH_4-N was higher than NO_3-N. The result show with increasing of hydraulic detention time and loading reduction can increase NH_4-N removal.

Effluent NH_3 ranged from 15 to 19 mg/L, with an average effluent of 7.18 mg/L, while the effluent ranged from 48 to 164 mg/L, with an average effluent of 120.25 mg/L.

Moderate strength effluent nitrate ranged from 48 to 164 mg/L, with an average influent of 120.25 mg/L, while the effluent ranged from 0.16 to 0.85 mg/L, with an average effluent of 0.036 mg/L in the best condition and moderate strength influent (Fig. 16, 17).

Macrophyte growth will increase phosphorus absorption, because Macrophyte growth can increase physical absorption and chemical precipitation. Off course phosphorus absorbed in Macrophytes will return to wetland sediment by biomass death and litter. Temperature effect on phosphorus removal is indirect. Temperature increase the macrophyte growth in warm season and its result is phosphorus absorption. Low strength effluent phosphorus ranged from 1.25 to 3.5 mg/L, with an average effluent of .032 mg/L, while the moderate strength effluent ranged from 5 to .5 mg/L, with an average effluent of 6.4 mg/L (Fig. 18).

The variation in the effluent TSS shown in Figure 18 is most likely related to internal TSS sources such as algal growth, sloughed epiphytes, animal sources, re-suspension, or detrital particles.

Influent TSS ranged from 112 to 256 mg/L, with an average influent of 112 mg/L, while the effluent ranged from 21 to 48 mg/L, with an average effluent of 5 mg/L. Fig. 19 shows the concentration of TSS in the treated effluent, were all within the upper limits set for municipal wastewater discharge to surface water in Iran. TSS efficiency ranged from 79.48 to 87.1 percent, with an average 83%.The basic mechanism of TSS removal is precipitation and filtration. This finding corroborates the ideas of Brix, H., [5] and Kadlec & Knight [7] who reported about the mechanism of TSS removal in the wetland.

Ammonia nitrogen effluent concentrations are poorly correlated with ammonia loading rates, due to the internal ammonia contribution from organic nitrogen (org N) associated with the TSS. Systems represented in the lightly loaded region generally showed low effluent ammonia levels.

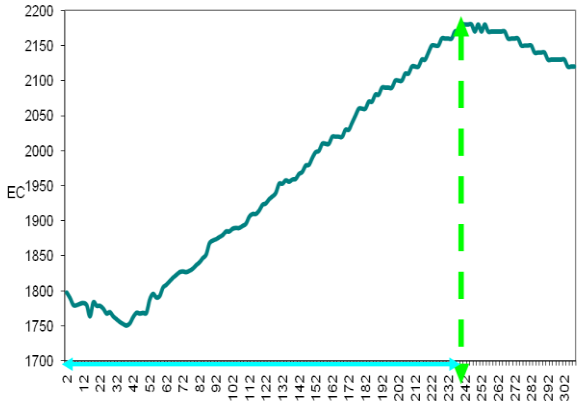

Fig. 4: Sample determination of optimum detection tiome by NaCl tracer method in high flow rate

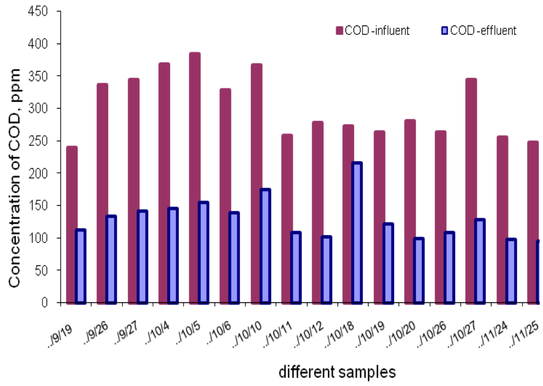

Fig. 5: COD changes in influent and effluent in winter

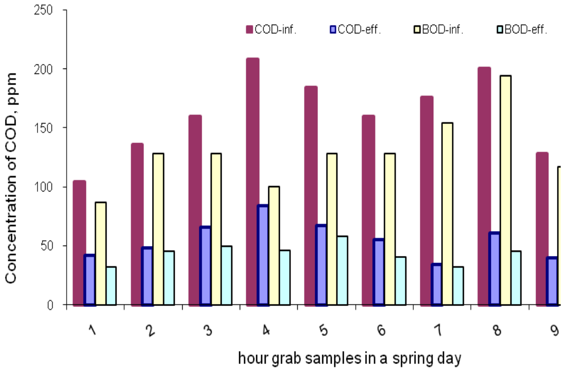

Fig. 6: COD and BOD_5 changes in influent and effluent in spring

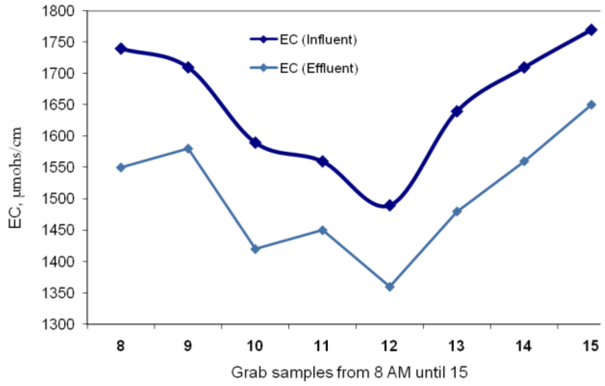

Fig. 10: EC changes of the system

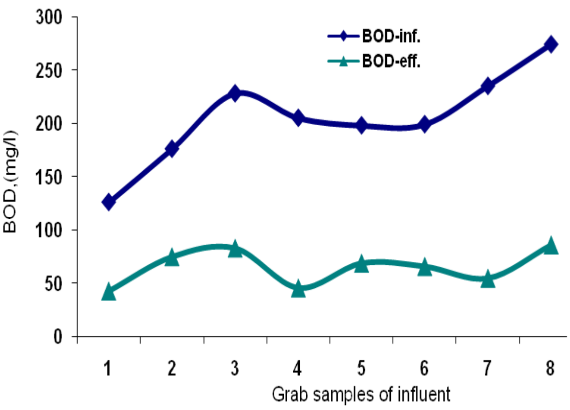

Fig. 7: BOD_5 changes (Moderate strengh influent)

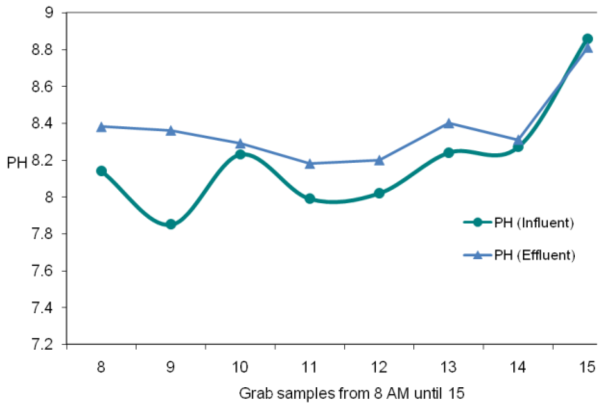

Fig. 11: pH changes of the system

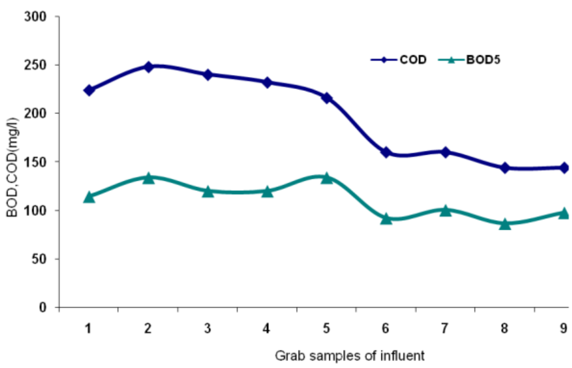

Fig 8: COD and BOD_5 changes (low stenght influent)

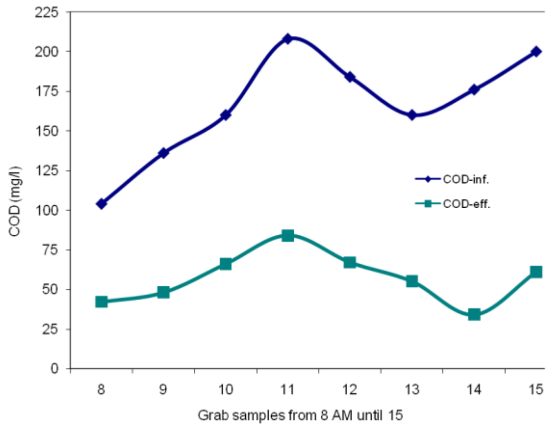

Fig. 12: COD changes (low strenght influent)

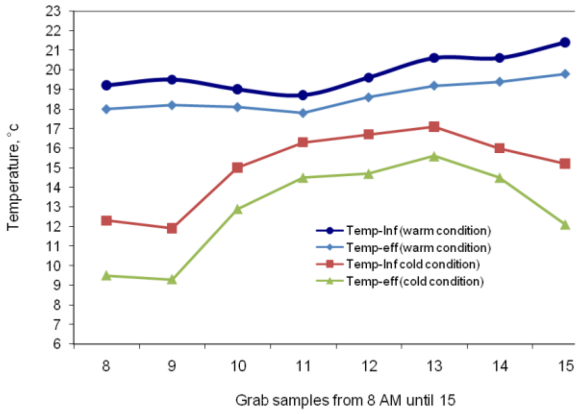

Fig. 9: Temperature changes in the system

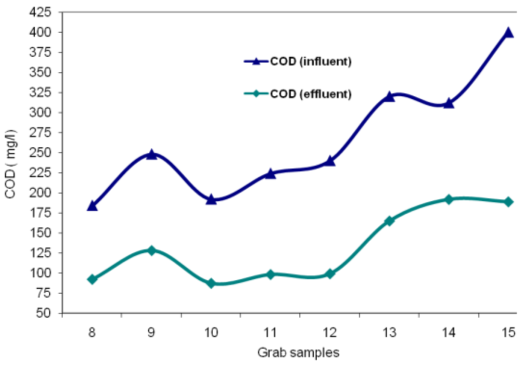

Fig. 13: COD changes (high strenght influent)

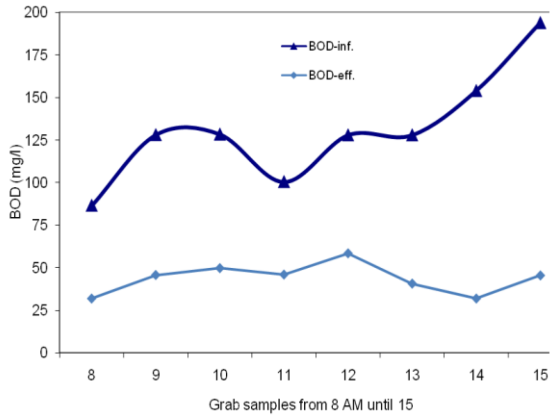

Fig.14: BOD_5 changes (low strenght influent)

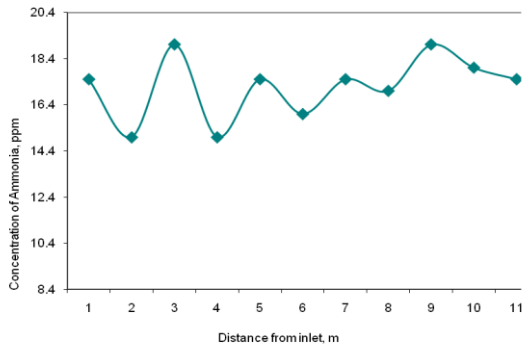

Fig 15: Ammonia concentration changes based on distances

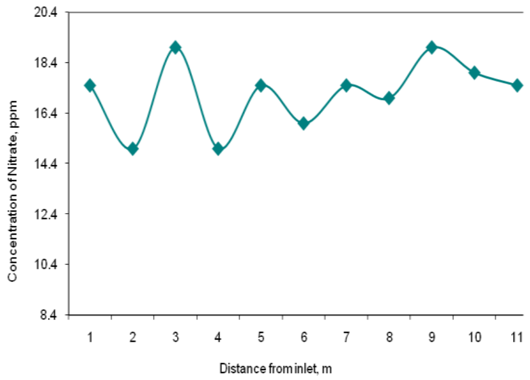

Fig. 16: Nitrate concentration changes based on distances

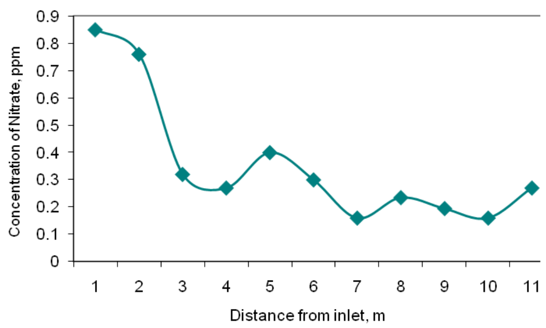

Fig 17: Nitrate concentration changes based on distances

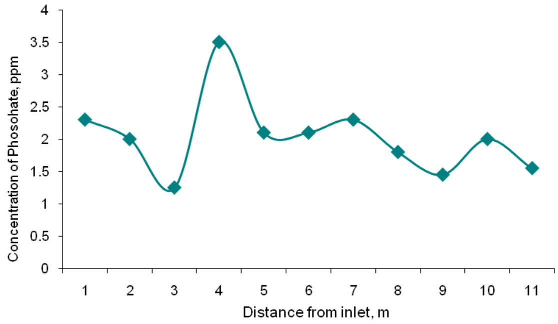

Fig. 18: Phosphorus concentration changes based on distances

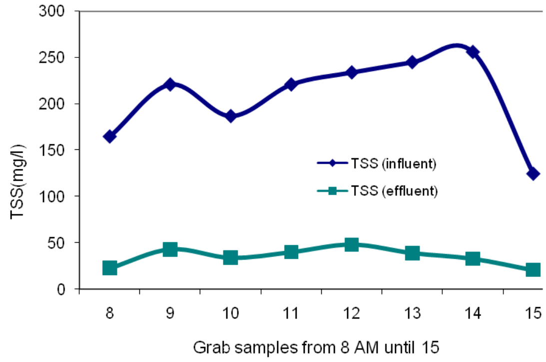

Fig. 19: TSS changes of the system

Conclusion

The study showed the system works as a buffering system for flow and pH. Efficieny of ammonia and Phosphourus were slightly increased in best condition. Macrophyte growth will increase phosphorus absorption, because Macrophyte growth can increase physical absorption and chemical precipitation. Offcourse phosphorus absorbed in Macrophytes will return to wetland sediment by biomass death and litter. Temperature effect on phosphorus removal is indirect. Concentration of COD,BOD, TSS and etc., in the treated effluent of moderate strength wastewater, were all within the upper limits set for municipal wastewater discharge to surface and agricultural water in Iran. Based on this study result, natural wetland can be success in BOD, COD, and TSS removal of the classical septic tank, but for nitrogen and phosphourus removal do not have considerable effects.

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