Available online at http://ijcpe.uobaghdad.edu.iq and www.iasj.net
Iraqi Journal of Chemical and Petroleum Engineering
Vol.20 No.2 (June 2019) 33 – 40
EISSN: 2618-0707, PISSN: 1997-4884

Performance of Subsurface Flow Constructed Wetland Systems in the Treatment of Al-Rustumia Municipal Wastewater using Continuous Loading Feed

Muna A. Rahi and Ayad A. H. Faisal

University of Baghdad

Abstract

This study aimed at comparing the performance of vertical, horizontal and hybrid subsurface flow systems in secondary treatment for the effluent wastewater from the primary basins at Al-Rustumia wastewater treatment plant, Baghdad, Iraq. The treatments were monitored for six weeks while the testsduration were from 4 to 12 September 2018 under continuous wastewater feeding for chemical oxygen demand (COD), total suspended solid (TSS),ammonia-nitrogen(NH_4-N) and phosphate (PO_4-P) in comparison with FAO and USEPA standards for effluent discharge to evaluate the suitability of treated water for irrigation purposes. Among the systems planted with *Phragmites Australia*, the hybrid subsurface flow system which consisted of vertical unit followed by horizontal one, considerably removed the pollutants more efficiently than the single operated systems. The planted hybrid subsurface flow wetland system was achieved the highest removal with a mean removal rate of COD,TSS, NH_4-N, and PO_4-Pat 99.3, 83.2,67.4 and 53% respectively and these percentages were decreased in the other systems. The results proved that the planted vertical subsurface flow unit can be removed the COD, TSS, NH_4-N and PO_4-Pwith values of 93, 71.1, 43.3 and 30.7%, respectively while the achieved removals by horizontal subsurface flow unit of 99, 74.3, 54.5 and 20.3%, respectively. The planted horizontal subsurface flow wetland, however, showed a good efficacy for all parameters in the treatment process except for PO_4-P when it is compared with vertical system, however, there is a clear increase in the NO_3-N effluent concentration for all treatment units.

Keywords: constructed wetlands, subsurface flow, wastewater treatment, wastewater parameters

Received on 06/03/2019, Accepted on 14/04/2019, published on 30/06/2019

https://doi.org/10.31699/IJCPE.2019.2.5

1- Introduction

The freshwater resources are becoming inadequate to fulfill demand with the growing global population, leading to a global challenge of freshwater scarcity. In its most recent annual risk report, the World Economic Forum lists water crisis as the massive global risk in terms of potential impact [1]. Many countries facing water scarcity during the last four decades, most of which are developing countries, are expected to increase to 34 by the year 2025 [2].

Due to the rapid growth of population and economic growth in Iraq, there is a serious water shortage problem through the increasing of demand on limited freshwater supplies and increased in wastewater volume discharged. Around the world, treated wastewater appears to be the only freshwater resource that is increasing as other sources are dwindling [3]. Direct disposal of untreated wastewater to water bodies and land has a negative impact on human health, then sufficient wastewater treatment for reuse will hence be a feasible option in ameliorating water scarcity challenge and environmental degradation, moreover, the treated wastewater may be formed a non-conventional water sources for satisfying the increase in demand rate for freshwater.

In Iraq, there are eleven major wastewater treatment plants with a total capacity of 650000 m^3/day and usually, they are located near the river banks of Euphrates, Tigris, Diala, Kahla, Diwaniyah, Husseinya and Shatt Al-Basrah.

The adopted treatment scheme processes in the plants consisted of traditional steps and can be arranged as preliminary, primary, and secondary treatment systems [4].

These systems required many requirements such as facilities, sanitary collection, as well as treatment and disposal of wastewater to decrease and/or remove the concentration of familiar components like BOD_5, COD, total suspended solids (TSS), and nutrients to ensure that the final effluents will not cause additional pollution.

The main advantages of those techniques are the best control on the treatment process and, also, the required area for construction of this project can be acceptable.

Traditionally, the spread of the rural population in many villages and the high cost of wastewater conveyance system and treatment beside their own properties and conditions would require decentralized wastewater treatment plant.

Corresponding Authors: Name: Muna A. Rahi , Email: munaaziz21@gmail.com, Name: Ayad A. H. Faisal, Email: ayadabedalhamzafaisal@yahoo.com

Therefore, these technologies must be robust and capable of operating with minimal maintenance or supervision are of great value for the local population and are expected to be the only feasible alternative for conventional wastewater treatment [5].

Constructed wetlands (CWs) have developed rapidly over the past decades and recognized as quick solutions or alternatives to conventional mechanical treatment systems in many countries particularly those located in arid and semi-arid areas due to their uncomplicated construction of local materials and easiness for uneven flow of wastewater as well as simple operational and maintenance requirements [6]. CWs are artificial wastewater treatment systems designed into engineered systems to treat wastewater by removing pollutants from contaminated water by using natural processes that occur in natural wetlands [7]. In addition, their natural form enables easy incorporation into the existing landscape [8].

CWs can be classified according to water flow into surface and subsurface flow systems, which are currently, the most used [9]. Water did not surpass the upper surface of the stone bed, which preferred to surface flow CWs for concerns about human contact with untreated wastewater, mosquito and odour control [10].

The vertical flow (VF) that is provided aerobic conditions, offer very efficient mineralization of organic matter and nitrification (the conversion of ammonium in wastewater to nitrates by organism oxidation as a metabolic process (aerobic process) using Nitosomonas bacteria, while nitrite converts into nitrogen by the denitrification in anaerobic process. Whereas horizontal flow (HF) usually preferred to other CW types when anaerobic processes for treating wastewater are sufficient, HF is most widely used for wastewater treatment, but VF systems are getting hold of popularity [11]. The compensation of various systems or several types of CWs arranged in a staged manner to form a hybrid system towards achieving better pollutants removal and treatment performance especially with respect to the nutrients components [12].

The key pollutants that affect the selection of the treatment process are suspended solids, organic material (BOD_5, COD), ammonia and organic nitrogen, phosphorus, in addition to the pathogenic organ, viruses, bacteria, protozoan, and helminth eggs [13].

The degradation and mineralization of organic matter occurs in both the bed substrate and the biofilms on reed plants [14], Vegetation has a minor function in the transformation and mineralization of nutrients and organic pollutants where the roots of the plants can be provided a bulky surface area for attachment of microorganisms that played the main role of organics degradation [15].

Plants roots also prevent wastewater from taking preferential paths in the substrate that can be affected on the hydraulic retention time in the wetlands [16].

In the subsurface CW systems, media material is an important factor because it could avoid clogging to ensure a sufficient hydraulic conductivity [17].

This study aims to investigate the ability of different CWs systems namely; vertical, horizontal and hybrid subsurface flow configurations in the continuous mode of loading feed for reclamation of the real municipal wastewater for irrigation purposes.

This work is a part of the study conducted on the various systems of the CWs under batch and continuous modes of operation to test their feasibility in the treatment process.

2- Experimental Work

2.1. Study Site Description

Al-Rustumia wastewater treatment plant; the third expansion project is located at the left side of the Tigris river in the direction of flow within Baghdad city/ the capital of Iraq located at 33° 17′ 15.41″ N 44° 31′ 55.76″ as seen in Fig. **1**. This project is serving the eastern areas of the army channel; precisely, the new Baghdad, first and second Sadar, Al-Ghadir and Al-Shaab regions [18].

The choice of this location for constructing the experimental facility of the present study was related with a number of considerations such as; the similarity in the objectives and environmental circumstances between the sanitary wastewater treatment plant (WWTP) and the constructed wetland, as well as the presence of laboratory building for achieving the planned measurements.

In addition, the facility is unique in the fact that it is located adjacent to the wastewater treatment plant, enabling all of the pilot-scale systems to receive the same municipal wastewater with required quantities through the operation process.

Raw wastewater, supplied to the units of the constructed wetlands, was taken from the effluent collection point of the three primary basins to ensure the amounts of the suspended solids as low as possible.

Fig. 1. The CW system location within Al- Rustumia wastewater treatment plant, Baghdad

2.2. Experimental Design and Layout

The treatment systems consist of vertical, horizontal, and hybrid subsurface flow wetland system planted with *Phragmites Australia*. The wetland units (**Fig. 2**) included one planted horizontal flow (HF_p) system, one planted vertical flow (VF_p) system and one planted hybrid system which composed of vertical flow unit followed by horizontal flow (VF_p-HF_p). All the CW units have the same size (length of 2.85m, width of 1.2m and depth of 0.8m), shape, flat bottom and equal aspect ratio (length to width). The units were manufactured from steel structures that fitted with fiberglass sheets of 10 mm thick. This is very important to avoid any chemical reactions between the steel structure and wastewater, prevent uncontrolled filtration and provide an environment that identical to the conditions of soil. The units were provided with openings located at the bottom for backwash cleaning and maintenance purposes.

Fig. 2. The pilot-scale CW units manufactured in the present study within Al-Rustumia wastewater treatment plant/ the third expansion project

The design of CW units used in this study was the same as the pilot-scale treatment system of Langenreichenbach ecotechnology research facility installed in Germany [19].

As seen in Fig. **3**, the filling materials in VFp were arranged in four layers according to the size of the particles. These layers are organized from the bottom of the basin as follows; 0.15 m coarse gravel of 16-40 mm, 0.15 m medium gravel of 8-16 mm, 0.2 m fine gravel of 4-8 mm, and finally 10 cm coarse sand of 1-3 mm..In order to provide good aeration through the VFp unit, the number of techniques was used to supply oxygen in addition to that oxygen afforded via the roots of plants e.g., wastewater was injected from the top of the bed through the system of pipes called distribution network which consisted of 2-in diameter polypropylene pipes. Four pipes installed along the length of the bed and two lateral pipes located at 5 cm above the packed bed, the openings with a diameter of 13 mm were chosen with uniform peripheral distribution spacing equal to 10 cm of openings around each pipe.

This location will provide a good contact with air for more air supplied into the substrate, a collection network which consisted of seven perforated pipes installed laterally with two longitudinal manifolds used to collect the percolated water, the diameter of the pipes in the collection network is similar to that of distribution network with diameter of openings equal to 15 mm and they spaced at distances equal to 10 cm. The VFp unit is also provided with aeration tube to equip the system with additional ventilation. The HFp was filled with medium gravel (grain size 8-16 mm) up to a height of 0.6 m.

Two compartments of 0.30 m at the inflow and outflow points were filled with coarse gravel (grain size 40-60 mm) to protect and avoid potential clogging of the inflow/outflow pipes with time.

The wastewater was supplied slowly to the bed of CW through the perforated polypropylene pipe of 100 mm diameter that placed in the inlet zone at the top of coarse gravel compartment; subsequently, the water was collected by another perforated pipe of 100 mm diameter, which placed in the bottom of the outlet zone. From the first stage of a plantation, the units were fed by intermediate loading with a hydraulic retention time of 5 days till the middle of August 2018. When one year of the plantation was passing, a continuous feeding operation was started where the CWs were operated with a wastewater flow rate of 450L.d^{-1} i.e. 0.131 m/d as a hydraulic loading rate. There was no clogging through the beds along with the duration of treatment processes.

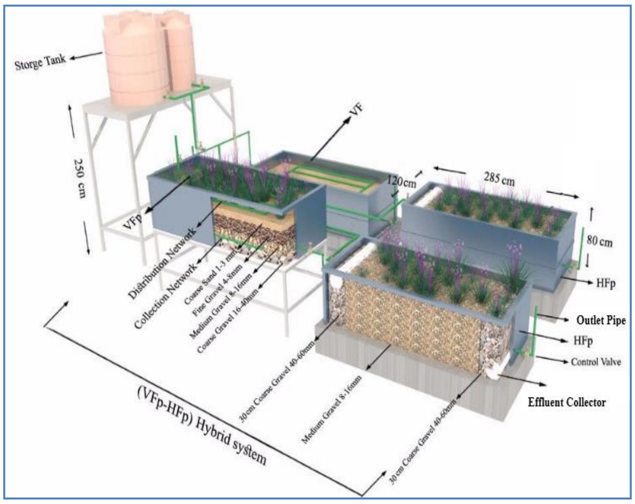

Fig. 3. Schematic representation of the pilot-scale wastewater treatment plant using subsurface flow CWs

2.3. Vegetation

Phragmites australis, (common reed) as a native plant that is widely available in vast quantities through the environment of Iraq especially in the natural marshes located at the southern regions having the following properties

- Bearing the environment of immersion, can withstand high levels of salinity and pollutants.
- Having a large exterior surface that are provided to the bacteria, yeast, and fungi that required for degradation of contaminants.
- Supplying a high level of oxygen, to ensure aerobic processes in the treatment zone, and have deep roots.
- Living all around the year.
- Fast growing and spreading.

Also, the very extensive root system creates channels for the water to pass through and provide the means for the secondary restructuring of the reed bed substrate system. Phragmites australis was selected for the plantation process in constructed wetlands furthermore its availability within the primary and aeration tanks of Al-Rustumia treatment plant [20].

This means that the choice of the reed plant may be a suitable decision because it will reduce the required maintenance for mentioned tanks and the plant is already acclimated with the same type of wastewater that will treat in the present experimental facility. During the second half of September 2017, healthy plants were removed from the aeration beds and trimmed to a height of 0.15 cm, planted into the experimental units to ensure rapid growth as mentioned in [9] with a density of 8 plants/m^2 which comparable with [21][21], [22]

2.4. Water Sampling and Quality Analysis

The water samples were collected at the inlet and outlets of the planted CWs using 0.5 L clean plastic bottles. Three times a week, sampling for each treatment for 2 weeks from 2nd September to 15th September 2018 was done in duplicates. The samples were transported directly to the laboratory. Water quality parameters (i.e., COD, NH_4-N and PO_4) were determined using HACH LANG spectrophotometer. TSS was measured according to 2540-D, Total Suspended Solids dirt (mg/100mL) at 103-105^oC by using Gravimetric filtration (0.45μm pore diameter filter). The tests were according to the standard methods for the examination of water and wastewater [23]. All tests were done in the chemical laboratory of Al-Rustumia wastewater treatment plant.

2.5. Removal Efficiencies of Pollutants

The removal efficiencies of the chosen wastewater parameters were calculated according to Equation: 1.

$$\text{RemovalEfficiency}(\%) = \frac{C_i - C_e}{C_i} * 100 \quad (1)$$

Where:
C_i = Influent Concentration (mg/L)
C_e= Effluent Concentration (mg/L)

3- Results and Discussion

3.1. Phragmites Australis Monitoring

The gravel that used for building purposes was chosen as the bed material for *Phragmites australis* implementation, their densities have been increased dramatically within all the vegetated CW units from 8 plants/m^2 at plantation in September 2017 to reach 108plants/m^2after 9 months from plantation process and then to reach 112-115 plants/m^2 in September 2018. Their average height was more than 1.5 m.

This type of reed has good growth ability and, during the summer season, it seems that the foliage branches of common reeds suffered and looked to be yellow and dry.

The optical condition may be due to temperature rising which was around 50^{0}C or because of pollutants accumulation in plant tissues. Previous studies pointed out that this problem could be solved by trimming stems and added them to the experimental unit for nature reproduces [8].

The monitoring of the treatment process in the present work was begun in the 2 September until 12 September 2018 where the density of the plants reached to the stable state with a value equal to 112-115 plants/m^2.

3.2. Organic Materials (COD) Removal

Effluent and influent COD concentrations for all the wetland units were measured during the monitoring period and plotted in Fig. **4**. The mean influent COD concentration was 321.5mg/L.

Among the three CWs units, the hybrid system can be caused a significant reduction in the effluent COD where the lowest mean value of 2.7 mg/L followed by the HFp of 4.2 mg/L and VFp with the value of 17.7 mg/L.

Higher COD removal rates might be related to physical processes such as filtration, sedimentation, and adsorption that can be achieved in CW units in addition to biological degradation.

The more efficient treatment by the hybrid system could be recognized from high removal efficiencies.

This can be attributed to the passing of wastewater through VFp and, then, HFp systems where this configuration can be optimized between the advantages and disadvantages of vertical and horizontal units when operated as a single system and the result will be the high efficiency in the treatment process.

The standards of France for organic matters present in treated wastewater that could be reused for irrigation purposes, represented by COD concentration <60 mg/L for all crops except those consumed raw food crops [24], consequently, each effluent of the three CWs is within the accepted France standards and also the present results are satisfied with acceptable limits of USEPA (2006).

The aerobic conditions of the VF wetlands support organics, TKN and NH_4-N removals, but any change in operational improvements are considered critical for VF wetlands [25], so as the system became always saturated, as a result the environment of the microorganisms within the VFp unit has changed, hence, the HFp was best than the VFp in organic material removal as shown in the same figure. The previous study such as [26] pointed out that, in the continuously loaded reactor, the constant addition of wastewater created laminar flow inside the media that could have inhibited homogeneous mixing. The authors reported that rapid addition of substantial wastewater amount in the intermittently loaded reactor resulted in forcing the flow of wastewater through aerobic-anaerobic conditions due to water turbulence inside the media which enhanced the biodegradation of organic matters in the VFp, where this consequence conditions facilitated the growth and proliferation of aerobic microbes.

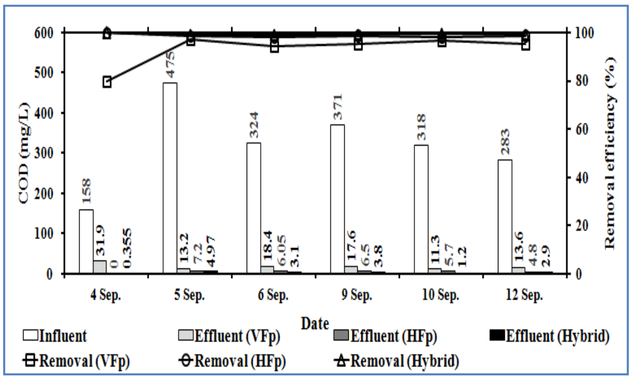

Fig. 4. COD concentrations and removal values in VFp, HFp and hybrid wetland systems

3.3. Nutrients Removal

The nitrogen compounds are of importance beside the organic materials; the inorganic forms of nitrogen (i.e. NH_4-N and NO_3-N) were measured within the CWs treatment units as an indicator of nutrients present in treated wastewater during the observation period. The NH_4-N and NO_3-N concentrations in influent and effluent for all the units are presented in Fig. **5**.

The influent concentration of NH_4-N was 59.5mg/L, while the effluent concentrations for hybrid CW units was 15.7 mg/L followed by the HFp and VFp with values of 23.7 and 28.8 mg/L respectively. The standards of FAO for NH_4-N concentration in treated wastewater that could be reused for irrigation purposes ranged from 5-30 mg/L [2], which mean that all CWs treatment units achieved an acceptable percentage of treatment so that ammonia-nitrogen concentrations in the treated water were acceptable with these standards.

The best removal of NH_4-N was achieved in the hybrid unit with mean value of 67.4% that could be linked to the long contact time that allowed simultaneous organic as well as nitrogen removal via anaerobic microbial route and microbiological processes in the gravel used as substrate where these results are consistent with observations of study presented by [27].

The mean value of NH_4-N removal within the HFp was 54.5% while the VFp removal rate can be reached to 43.3% and this may be indicated to the lack of sufficient oxygen that hindered the nitrification route. Since the unit is always saturated with wastewater due to the continuous feeding, anaerobic conditions will be predominant, in that case, better aeration must attain, to enhance the nitrification process and subsequently, the formed nitrates are easily utilized by the plants.

Fig. **6** showed that the influent concentration of NO_3-N was 1.6 mg/L, while the mean effluent concentrations were 1.7, 2.1 and 3.8 mg/L for HF_p, hybrid and VF_p respectively. The NO_3-N limitation illustrated by FAO 2003 was in the range (0-5 mg/L) to reuse the treated wastewater in agricultural irrigation [2], and then the effluents from all units were within these limits. The decrease in NH_4-N combined with the nonappearance of increase in NO_3-N indicates that the system conditions allowed for some denitrification. This process is only happened at organic availability in anaerobic or anoxic conditions, it occurred at a rate similar to nitrification so that there appears to be no change in NO_3-N concentration. This situation appeared in HF and hybrid systems; on the contrary, the NO_3-N concentrations have been increased in the VF_P, indicating for some restricted or limited conditions for denitrification process. This can be attributed either to the distribution method of water through the distribution network or due to the presence of the aeration pipe.

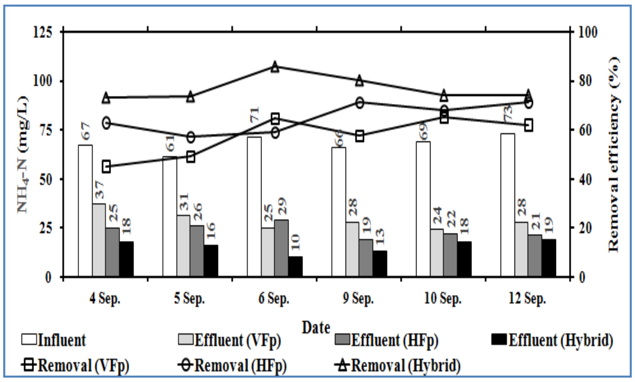

Fig. 5. NH_4-N concentrations and removal values in VFp, HFp and hybrid wetland systems

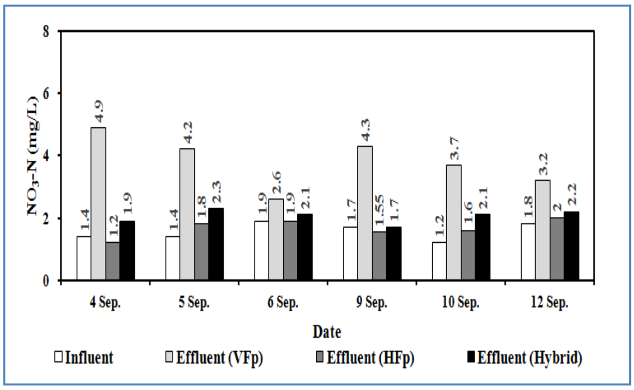

Fig. 6. NO_3-N concentrations in VFp, HFp and hybrid wetland systems

3.4. Ortho Phosphate-Phosphorous Removal

Despite its role as a fundamental nutrient for plants in aquatic ecosystems, the excessive PO_4-P concentrations could cause eutrophication and algae growth in the water body [28].

Fig. **7** presents the phosphate phosphorous (PO_4-P) concentrations in the effluent and influent water for systems under consideration during the observation period.

The lowest values of PO_4-Pconcentrations can be recognized in the hybrid system in comparison with other systems where the mean removal efficiency equal to 53% and this value was decreased in the VFp and HFp to become 30.7 and 20.2% respectively.

This means that the mean values of effluent concentrations for PO_4-P were 2.4, 2.8 and 1.6 mg/L for VF_p, HF_p and hybrid systems respectively, while the influent concentration equal to 3.5 mg/L.

The presence of plants in all the CW units could further polish the wastewater as stated by [28] so phosphate concentrations decreased in the planted units. However, other study [29] illustrated that phosphorus removal was approximately similar in planted and unplanted units, as media controlled phosphorus removal route.

Also additional study stated that although orthophosphates can be removed by chemical precipitation in the filter materials, well-heeled with Ca/Fe/Al contents and can be degraded biologically; polyphosphates often undergo hydrolysis process but the typical removal of phosphorus observed in subsurface flow wetlands is generally influenced by media chemical adsorption route and physical precipitation of ions [30].

The difference in the removal efficiencies between the systems might refer to the larger surface area of VFp media due to different layers that might offer best adsorption surfaces comparing to HFp.

According to FAO (2003), the total phosphorus allowed in wastewater to reuse safely for agriculture purposes was specified between 0-2 mg/L [2], thus only the hybrid unit is within this standard while the VFp and HFp need more improvement to increase their removal rate.

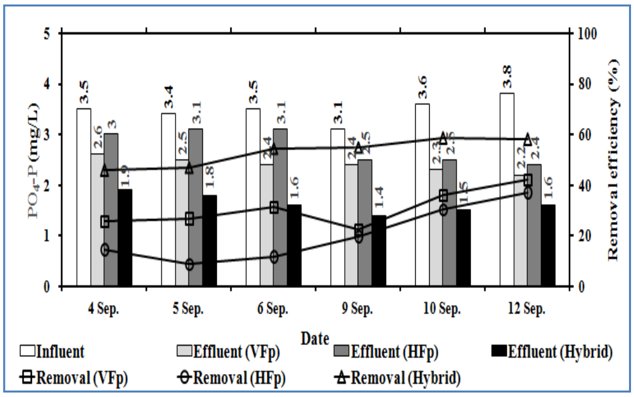

Fig. 7. PO_4-P concentrations and removal values in VFp, HFp and hybrid wetland systems

3.5. Total Suspended Solids Removal

Total suspended solid (TSS) in the influent and effluent concentrations for all systems during operation period can be plotted in Fig. **8**.

The results proved that the hybrid system plays a significant role in the treatment of the wastewater where the mean effluent concentration of TSS equal to 12.8 mg/L with highest removal efficiency reached to the 85%. This figure signified that the effluent concentration of TSS from VFp was higher than that of HFp with mean values equal to 22.2 and 19.7 mg/L respectively were the identical achieved removal efficiencies of 71.1 and 74.4%.

The best performance of the hybrid system could be attributed to the longer wastewater retention in the substrate in comparison with other systems due to the presence of two types of CW. Also, the processes of sedimentation and filtration might be enhanced due to the reed roots that have slowed down the velocity of wastewater through the media thereby increasing the retention time which consequently improved removal level.

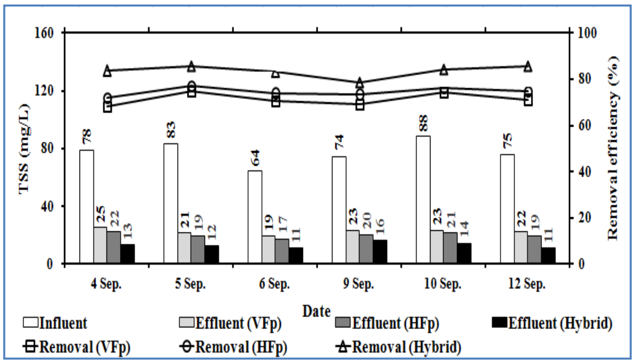

Fig. 8. TSS concentrations and removal values in VFp, HFp and hybrid wetland systems

4- Conclusions

The present results proved that the constructed wetlands of different configurations are effective in the removal of most pollutants in the real municipal wastewater. Among the subsurface flow wetland systems planted with the common reed, the hybrid system attained significantly the highest removal of COD, TSS, NH_4-N, and PO_4-P with values of 99.3, 83.2,67.4 and 53% respectively, compared to the horizontal and the vertical subsurface flow systems.

The horizontal subsurface flow system also performed significantly better in COD, NH_4-N and TSS removal compared to vertical system except in PO_4-P removal, this might due to the changing of operation condition which has a significant effect on the performance of the vertical system.

Overall, through the continuous loading the hybrid system planted with *Phragmites Australia* being the best in pollutants removal and it can be used as a substitute of the secondary treatment in the traditional municipal wastewater treatment plant.

Acknowledgments

We are sincerely grateful to Al- Rustumia wastewater treatment plant staff for allowing us to set up the experimental units at their wastewater treatment plant site. Thanks also to the Environmental Engineering Department, University of Baghdad for offering us the technical support.

References

[1] Hoekstra, A. and Mekonnen M. (2016). "Four billion people facing severe water scarcity." Science Advances, 2(2).

[2] Almuktar, S., Abed, S. N., and Scholz, M. (2018a). "Wetlands for wastewater treatment and subsequent recycling of treated effluent: a review". Environmental Science and Pollution Research, 25(24), 23595–23623.

[3] Abdul-Fattah, M. Ali (2011) "Reuse of domestic wastewater for irrigation: conceptual and basic design elements. " Iraqi Journal of Chemical and Petroleum Engineering Vol 12 No 1 (2011).

[4] Aquastant,(2008) "Irrigation in the Middle East region in figures – AQUASTAT Survey 2008", Report, 2008.

[5] LI, J. (2010). "Application of Decentralized WastewaterTreatment in Small towns and Villages of China." A report no. 2010:15 submitted to Department of Energy and Environment Division of Environmental Systems Analysis Chalmers University of Technology Göteborg, Sweden

[6] Vymazal , J. (2010) "Constructed Wetlands for Wastewater Treatment',. Water 2010, 2(3), 530-549;

[7] Vymazal, J. (2011). "Constructed wetlands for wastewater treatment: Five decades of experience.". Environmental Science and Technology. 45 (1), 61–69.

[8] Stefanakis, A. I., and Tsihrintzis, V. A. (2009). "Performance of pilot-scale vertical flow constructed wetlands treating simulated municipal wastewater: effect of various design parameters." Desalination. 248(1–3), 753-770.

[9] Stefanakis, A., Akratos, C. S., and Tsihrintzis, V. A. (2014). "Vertical Flow Constructed Wetlands." 1st Edition, Eco-engineering Systems for Wastewater and Sludge Treatment, Elsevier Science.

[10] Wu, S., Kuschk, P., Brix, H., Vymazal, J., and Dong, R. (2014). "Development of constructed wetlands inperformance intensifications for wastewater treatment: A nitrogen and organic matter targeted review." Water Research, 57, 40-55.

[11] Vymazal, J. (2015). "The role of natural and constructed wetlands in nutrient cycling and retention on the landscape."

[12] Taheriyoun, M., and Rad, M. (2017). "Simulation of organics and nitrogen removal from wastewater in constructed wetland." European Water, 58, 135-141.

[13] Khairallah A. and Abass, Z.(2011). "Improving Nutrient Removal in Constructed Wetland Wastewater Treatment", Journal of Petroleum Research and Studies, vol. 136 no. 3, pp. 74–87, 2011.

[14] Kouki, S., M'hiri, F., Saidi, N., Belaïd, S., and Hassen, A. (2009). "Performances of a constructed wetland treating domestic wastewaters during a macrophytes life cycle." Desalination. 246(1–3), 452-467.

[15] Shama, S., Perveen, I., Sumera, S. Ahmed, N. Ali, and Naeem, S.(2015) "A comparative study of macrophytes influence on wastewater treatment through subsurface flow hybrid constructed wetland", Ecological Engineering., vol. 81, pp. 62–69, 2015.

[16] Sayadi, M. H., Kargar, R., Doosti, M. R. and Salehi, H.(2012) "Hybrid constructed wetlands for wastewater treatment: A worldwide review", Proceedings of the International Academy of Ecology and Environmental Sciences, 2012, 2(4):204-222 .

[17] Raheek I. Ibrahim (2017), "Upgrading of Al-Rustamiyah Sewage Treatment Plant Through Experimental and Theoretical Analysis of Membrane Fouling" Iraqi Journal of Chemical and Petroleum Engineering, Vol 18 No 2 (2017).

[18] Nivala, J., Headley, T., Wallace, S., Bernhard, K., Brix, H., Afferden, M. Van, and Arno, R. (2013). "Comparative analysis of constructed wetlands : The design and construction of the ecotechnology research facility in Langenreichenbach , Germany." Ecological Engineering, Elsevier B.V., 61, 527–543.

[19] Alanbari M. Ali and Muter, M. Salim (2018) "Evaluation of Environmental Sustainability Indicators of Northern Rustimeh Wastewater Treatment Plant in Baghdad, Iraq, Using Simapro7.1 Program", Journal of Engineering and Sustainable Development, vol.22 , no. 05, pp. 188–199, 2018.

[20] Toscano, A., Langergraber, G., Consoli, S., and Cirelli, G. L. (2009). "Modelling pollutant removal in a pilot-scale two-stage subsurface flow constructed wetlands." Ecological Engineering, 35(2), 281–289.

[21] Borin, M., Politeo, M., and Stefani, G. De. (2013). "Performance of a hybrid constructed wetland treating piggery wastewater." Ecological Engineering, (51), 229– 236.

[22] APHA , A., Water Environment Federation (2012) "Standard methods for the examination of water and wastewater. " manual, Washington DC, USA.

[23] Jeong, H., Kim, H., and Jang, T. (2016). "Irrigation water quality standards for indirect wastewater reuse in agriculture: A contribution toward sustainablewastewater reuse in South korea." Water (Switzerland), 8(4), 169-187.

[24] Zhao, Y.Q., Babatunde, A.O., Hu, Y.S., Kumar, J.L.G., and Zhao, X. H. (2011). "Pilot field-scale demonstration of a novel alum sludge-based constructed wetland system for enhanced wastewater treatment." Process Biochem., 45(1), 278–283.

[25] Caselles-Osorio,J. and Garc ıa, A. “Impact of different feeding strategies and plant presence on the performance of shallow horizontal subsurface-flow constructed wetlands’, Science. Total Environment., vol. 378, no. 3, p. 253–262., 2007.

[26] Bialowiec, A., Janczukowicz, W., and Randerson, P. (2011). “Nitrogen removal from wastewater in vertical flow constructed wetlands containing LWA/gravel layers and reed vegetation.” Ecological engineering, 37(6), 897-902.

[27] Raghad F. ALmilly, Mohanned H. Hasan(2017) “Waste Water Treatment by Liquid-Solid Adsorption Using Calcined Sand-Clay Mixture Adsorbent.” Iraqi Journal of Chemical and Petroleum Engineering Vol 18 No 2 (2017).

[28] Herouvim, E. S. A. V. V. (2011). “Treatment of olive mill wastewater in pilot-scale vertical flow constructed wetlands.” Ecological Engineering, 37(6), 931–939.

[29] Vohla, C., Kõiv, M., Bavor, H. J., Chazarenc, F., and Mander, Ü. (2011). “Filter materials for phosphorus removal from wastewater in treatment wetlands-A review.” Ecological Engineering. 37(1), 70-89.

كفاءة اداء الاراضي الرطبة المشيدة التي تعمل بنظام الجريان تحت السطحي لمعالجة مياه وفق نظام التغذية المستمر الصرف الصحي لمحطة الرستمية

الخلاصة

تهدف هذه الدراسة إلى مقارنة أداء ثلاث وحدات معالجة تعملبأنظمة الجريانتحت السطحي(العمودي والافقي والهجين) المعتمدة في المعالجة الثانوية لمياه الصرف الصحي المتدفقة من الأحواض الأولية في محطة معالجة مياه الصرف الصحي في الرستميه في بغداد. كان التشغيلوالمراقبة بنظام التغذية المستمرة لمياه الصرف الصحيلمدة ستة أسابيعبينما تم اخذ العينات واجراء الفحوصات للمياه الداخلة والخارجةلمدة اسبوعين . تم مراقبة تراكيزكل من الأكسجين الكيميائي المطلوب والمواد الصلبة الكلية العالقة والأمونيا والنترات والفوسفات مقابل معايير منظمة الأغذية والزراعة ومعايير الولايات المتحدة الامريكية لغرض اعادة استخدام المياه الناتجة لأغراض الري.جميع الوحدات كانت مزروعة بنبات القصب المحلي. عند مقارنة اداء الانظمة كان نظام التدفق تحت السطحي الهجين الذي يتألف من وحدةعمودية تليها وحدة أفقية هو الافضل من بين الأنظمة المزروعة لتمكنه من ازالة الملوثات المختارة في الدراسة بشكل أكثر كفاءة من الأنظمة التي تعمل منفردة. وحقق هذا النظام الهجين متوسط معدل ازالة لكل مما ياتيCOD و TSS و NH4-N و PO4-P عند 99.3 و 83.2و67.4 و 53٪ على التوالي مقارنةً بأنظمة الأراضي الرطبة الأخرى. تمت إزالة وحدة التدفق العمودي تحت السطحي COD، TSS و NH4-N و PO4-P عند 93 و 71.1 و 43.3 و 30.7٪ على التوالي بينما حققت وحدة نظام التدفق تحت السطحي الأفقي إزالة COD و TSS و NH4-N و PO4-P في 99 و 74.3 و 54.5 و 20.3٪ على التوالي. أما الأراضي الرطبة افقية الجريان تحت السطحي فقدأظهرت إزالة أفضل لمعالجالمياه باستثناءالفوسفات مقارنة بالإزالة التي تم تحقيقها بواسطة نظام التدفق العمودي تحتالسطحي.كان هناك ارتفاع في تركيز النترات لجميع وحدات المعالجة.

الكلمات الدالة : اراضي رطبة مشيدة، جريان تحت سطحي، معالجة مياه الصرف الصحي،عوامل مياه الصرف الصحي