Pak. J. Agri. Sci., Vol. 57(3), 837-847; 2020
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
DOI:10.21162/PAKJAS/20.9571
http://www.pakjas.com.pk

DESIGNING AN EFFICIENT WETLAND BY DECISION SUPPORT SYSTEM USING EXPERIMENTAL AND MODLING APPROACH

Syed Tanvir Arshad Saadi[1,*], Muhammad Arshad[1], Muhammad Uzair Qammar[1] and Muhammad Anwar ul Haq[2]

[1]Department of Irrigation and Drainage, Faculty of Agricultural Engineering and Technology, University of Agriculture Faisalabad, Pakistan; [2]Institute of Soil and Environmental Sciences, Faculty of Agriculture, University of Agriculture Faisalabad, Pakistan
***Corresponding author's e-mail: stasaadi@gmail.com**

Pakistan is facing the most horrible disasters of water scarcity since two decades. Due to which wastewater is directly used for agriculture without secondary and tertiary treatments which is affecting the soil, plant and human health negatively. In this study wetland technology was used for the biological treatments of waste water using aquatic plants for irrigation. In a prototype experiment, different effluents were treated and their optimal hydraulic retention time (HRT) was found. A comparison was made between predicted and observed values after using a modeling approach. RCBD experimental design with three treatments was selected for the study, where each treatment had three replications. Water lettuce (*Pistiastratiotes* L.), pennywort (*Centella asiatica* L.) and duckweed (*Lemnoidea elemna* Minor L.) aquatic plants were used for wastewater treatment. The wastewater quality was analyzed before and after treatment for particular parameters such asEC, Ca, Mg, Na and heavy metals including Fe and Cu. Sodium Adsorption Ratio (SAR) was also calculated on the basis of results of Ca, Mg and Na. Results showed the range of reduction efficiency of EC, Ca, Mg, Na and heavy metals 3-26%, 6-36%, 0-92%, 12-75% and 4-35%, respectively. On the basis of this study, development of decision support system (DSS) was made to design a constructed wetland (CW) which is most efficient for the treatment of various types of wastewater. Policy guidelines were established for the safe reuse of treated wastewater for irrigation purpose.
Keywords: Wastewater, constructed wetland, decision support system, aquatic plants.

INTRODUCTION

Pakistan ranks third in the world among countries facing acute water shortage. There is lack of water resources in more than half of the country. Due to this insufficiency, it has already been declared as water scarce country (Eberstadt 2010, IMF 2018). The share of agriculture in Pakistan's economy is 21.8% and 60% in GDP and employment, respectively (Pakistan Economic Survey, 2017). There is need for 210 BCM of water for agriculture to meet the irrigation requirements, whereas the surface and groundwater availability for agriculture is about 94 MAF and 38 MAF, respectively in Pakistan (Pakistan Economic Survey, 2018). By reason of this water scarcity, cultivated area is decreasing and to fulfill the crop water requirements, the farmers are installing tubewells in abundance, resulting in the rapid depletion of fresh groundwater layer. To overwhelm these problems, the storage of country's water resources is required on war footings. For this purpose a search for alternative strategies like treated wastewater to get water for irrigation have become essential (Hussain and Mumtaz, 2014).

Presently Pakistan produces 4.369 billion cubic meter per year of wastewater which includes 1.309 and 3.060 billion cubic meter per year from industrial and municipal use, respectively. This figure was 6.54 billion cubic meters per year in 2016 but no appropriate measures have been taken so-far for the utilization of this resource after treatment and its reuse for agriculture purpose. About 1.783 billion cubic meter per year wastewater disposed into major rivers without treatment which is 33 % of the total generated wastewater in Pakistan. It contains 1.439 and 0.345 billion cubic meter per year from municipal and industrial discharge, respectively (Maria, 2018). It is estimated that globally 20 million hectares of land is irrigated with wastewater supporting the livelihoods of a hundred million or more poor people (Drechsel *et al.*, 2010)

Agriculture sector is a major consumer of water but existing water resources are diminishing rapidly day by day. On the other hand, a huge amount of wastewater generated annually is wasted in the absence of any proper treatment mechanism. Although treatment plants are available in many cities of Pakistan but treatment of a small portion of their designed capacity i.e. 8% of total waste water is being done (Liu and Liptak, 2000)(Murtaza and Zia, 2012). Primary treatment of wastewater using conventional means is costly and a negligible amount of primary treatment is done in the country. On the other hand, secondary and territory treatment of wastewater is not done in the country. Hence to meet the water requirements, a new idea of wastewater treatment using CWs has been developed. The available water after treatment from CWs shall meet the permissible irrigation standards and can be used for irrigation of crops. Wastewater management technique using CWs can remove all harmful pathogens and bring heavy metals and nutrient loads within safe limits for use or disposal (Pescod, 1992). The CWs consists of aquatic plants called macrophytes, substrate comprising of sand/gravel media, column of water and living organisms. CWs are used for wastewater treatment in the entire world and have become low cost and economical alternative method for treatment of wastewater. Primarily CWs were used for elimination of nutrients in urban and suburban agricultural wastewater, sewage and storm water and its satisfactory results declared that CWs had good potential for the removal of pollutants. Ideally, pumps are not utilized to load wastewater in CW as the gravity flow is used in system design (Vymazal, 2010b). There are several reasons for adoption of CWs which include huge sedimentation area, increased plants growth and microbes; and higher up-taking proficiency of plants for removal of heavy metals (Maehlum, 1995). Rapid industrial development, massive utilization of heavy metals and environmental pollution of surroundings led the use of CWs for industrial wastewater treatment in the developing countries (Ensink *et al.*, 2002).

There are three main processes that take place within wetland for the treatment of wastewater; these include physical, biological and chemical processes. Sedimentation and filtration are done in physical process. After giving a reasonable detention time to the wastewater in large ponds, sedimentation occurs followed by filtration when the wastewater is passed through a filter media. In the biological process, plants uptake nutrients and heavy metals through their roots and metabolism. In the presence of aerobic and anaerobic bacteria, nutrients transformation takes place. In the third process called chemical process, water precipitation, oxygen absorption form decomposition reactions and atmosphere are the functions that take place in a CW that treat and clean wastewater. For the purification of wastewater, no chemicals are added because a number of natural processes take place in the CW that cleans the water(Chang *et al.*, 2013). There are three main types of CWs namely free water surface CW, Sub surface flow CW and hybrid CW. In this study free water surface (FWS) CW was used to treat wastewater. The experiment was carried out in Lahore where several manufacturing units relating to chemicals, fertilizer, leather tanning, paints, rubber, steel, sugar and vegetable ghee are producing wastewater. Regrettably most industries have no individual wastewater treatment plants, and even if present, it is not used due to non-presence of power and higher expenses for its functioning. This wastewater is directly disposed of without any primary, secondary or tertiary treatment into the surface drains or directly pumped into aquifer. The treatment plant for wastewater at Shadbagh town Lahore was constructed to treat municipal wastewater of the area but now a days plenty of untreated effluent of industry is mixed in it. Shadbagh drain have discharge of 200 cusec and Biochemical Oxygen Demand (BOD) level is 192 mg/L (Qureshi and Sayed, 2014); terminates in the River Ravi and has a large basin to treat wastewater. Water stays for a small time period and then flows to its ultimate disposal. These ponds can be converted into CW using engineering techniques and with some proper management. Direct disposal of untreated wastewater is affecting the ground as well as river water; hence causing the deterioration of water quality along with soil salinity. It has direct and indirect effect on human beings in a number of ways. The current research work is of novel nature in Pakistan and a little work has been carried out on constructed wetland in the world. The primary objective of CW designing and construction is to treat wastewater and to increasing the quantity of the treated wastewater. This treated wastewater can be used as an alternative to fresh water form any purposes such as irrigation of landscape, forest, food and nonfood crops (Hiley, 1995).

Limitations: Little first-hand information and detailed data is available for the study area due to the short study time and zero budgets for this research. Prototype experiments were performed and all the results were calculated on the basis of equations. Several important factors such as productivity of plant and changes in climate are not included in the analysis during the study although these are related to water consumption and have a major impact on the design of the constructed wetland.

MATERIALS AND METHODS

Experimental study was conducted to determine the potential of CW system for treatment of wastewater for irrigation at Lahore having semi-arid climate in Shadbagh Town situated at Latitude 31.5204°N, and Longitude 74.3587° E. Total area and population of Lahore city is about1772 km^2 and11.127 million, respectively. Total area and designed population of the study area is3.07 km^2 and 32564 persons, respectively (Rana, 2017).

Keeping in view the water scarcity problem of the available water resources an efficient CW based on decision support system was developed for treatment of wastewater. This prototype study was designed for checking the ability of CW to treat wastewater and to use it as an alternative source of usable water.

Research methodology: Following research methodology was adopted during the present study (Figure 1)

Outlet Basin

A prototype experiment was conducted to evaluate the treatment performance of Free Surface Flow CW for treating wastewater. Experiments were designed in RCBD. The system had three treatments and every treatment had three replications, planted with aquatic plants namely water lettuce, duckweed and pennywort. The cross-section of the treatments is shown in the figure 2.Each cell has the design elements based on the database collection. To store and distribute the wastewater a storage basin was mounted to each wetland cell. The size of storage basin was enough to meet the continuous wastewater supply to all wetland cells for consecutive days. Influent and effluent water samples were collected from each cell. These samples were tested and analyzed for given water quality parameters and these results were used to find out the most efficient design for wastewater treatment.

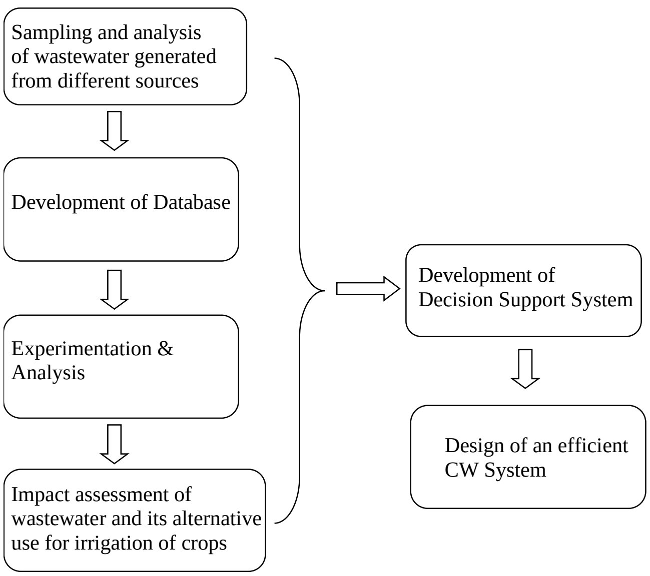

Figure 1. Development of decision support system (DSS)

Type and Structure of Wetland: In this study, free water surface flow (FWSF)) CW was selected for treating various types of wastewater. Following structure of Free Water Surface Flow CW had been adopted in this study

Inlet Basin

i. Pond1: (Water Lettuce) (60cm x 45cm x 30cm)
ii. Pond 2: (Duck Weed) (60cm x 45cm x 30cm)
iii. Pond 3: (Pennywort) (60cm x 45cm x 30cm)
iv. Storage Basin: (120cm x 120cm x 180cm)
v. Bedding/ Substrate:
    - Size of gravel (8-12 mm) diameter
    - Gravel Layer (15 cm thick)
    - Sand Layer (2.5 cm thick)

Experimental Layout for FWSF

Input: Domestic Wastewater

Three numbers of treatments with three replications per treatment

i. Treatment-1
    - Hydraulic Retention Time: 3-days
    - Plants: Water Lettuce, Duck Weed, Pennywort
ii. Treatment-2
    - Hydraulic Retention Time: 5-days
    - Plants: Water Lettuce, Duck Weed, Pennywort
iii. Treatment-3
    - Hydraulic Retention Time: 7-days
    - Plants: Water Lettuce, Duck Weed, Pennywort

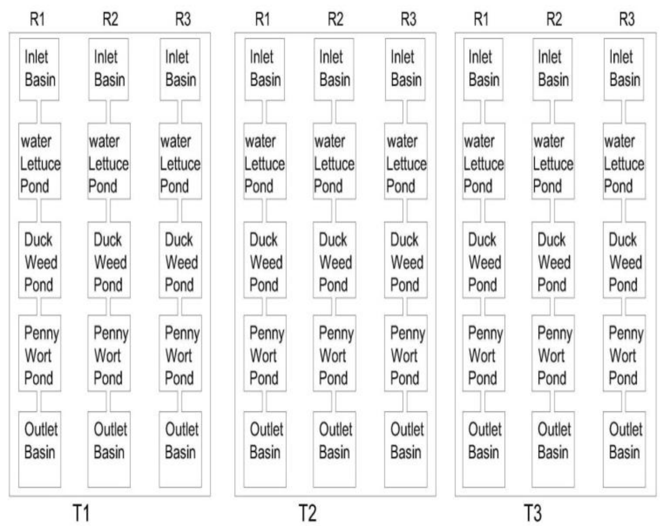

Figure 3. Experimental Layout for FWSF

Experimental development: The system was designed on an inflow rate of 10 liter per day wastewater with 3 containers with size 60 cm x 45cm x 30 cm in one replication. First, second and third treatments had 3, 5 and 7 days Hydraulic Retention Time (HRT). Also, treatments containers had a total storage capacity of 0.081m^3. These containers were connected with each other with help of a plastic joint and PVC

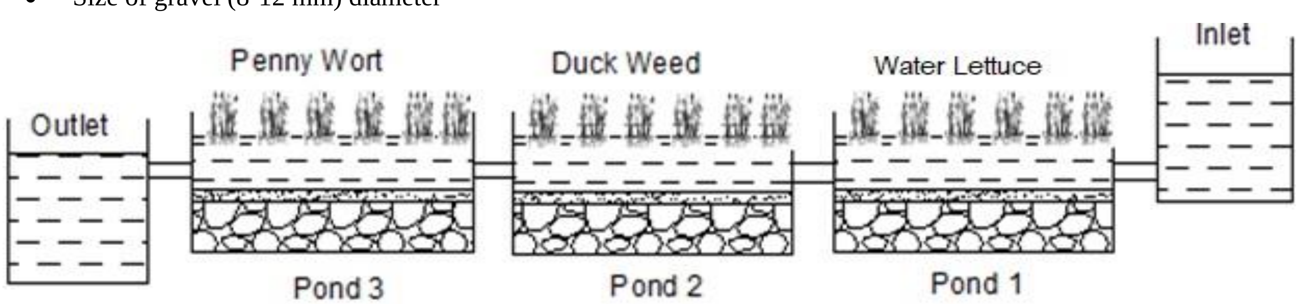

Figure 2.X-Section of FSF CW system

pipes by making a hole with the help of drill from bottom of containers up to designed height. These containers were working as ponds having plants within it. Water lettuce, duckweed and pennywort plants were planted in the first, second and third containers. Containers and storage tanks were connected with 2.5 cm diameter pipes. Each container except treated water collection containers had layer's thickness of 15 cm and 2.5 cm of gravel and sand respectively which were 25 % of its total storage volume. According to substrate condition, some amount (1.25-2.5 cm) of soil was also added so that the growth of plants becomes faster. A media was developed between the gravel and soil which included microorganism algae and fungi. This developed media played an important role in the treatment of wastewater after decomposing sludge; hence algae and fungi increased the availability of O_2 and BOD. Wastewater was collected from disposal station at Shadbagh town Lahore. After every 7 days, 300 liters wastewater was collected manually in canes. This collected water was stored in storage tank. Outflow of water from storage tank was controlled with the help of control valve.

In this research macrophytes plants were used to treat wastewater which were directly planted in the wet land cells. Due to change in environment and water conditions, due care e.g. polyethene cover was taken till the sustenance of the plant. After four weeks, plants were able to sustain themselves and started their new growth.

Parameters measured/tested include EC, SAR, Fe and Cu. Measuring/testing of physical and chemical parameters was carried out once in a week. Turbidity level was also checked by naked eye.

The EC was calculated using the model CE # TOA-1M-4OS. Calibration was carried out using a buffer solution of standard system.

Calcium (Ca) was measured using the following expression.

$$\text{Calcium (mg/L)} = \frac{\text{ml of EDTA used x 400.5 X 1.05}}{\text{volume of sample taken}}$$

Magnesium (Mg) was found as difference between total hardness and calcium hardness multiplying by factor 0.224.

Sodium was estimated using flame photometer and the results were compared using the following mathematical expression.

$$Na^{+} = \frac{\text{ppm from graph x dilution factor}}{\text{eq wt of Sodium}} \text{ x } 1000$$

SAR was calculated using the following expression.

$$SAR = \frac{Na+}{\sqrt{0.5\,(Ca+Mg)}}$$

Concentration of Fe and Cu in wastewater samples was determined by using Atomic Absorption Spectrophotometer (Hitachi Polarized Zeeman AAS, 2-8200, Japan) following the conditions described in AOAC (1990).

***Numerical equations used in model*:** The suggested model considered a homogeneous water zone as taken by Vervoort and van der Zee in eco-hydrological model (Vervoort and van der Zee, 2009).The total water balance with in the system remained constant because there was no leakage within the system throughout the period of treatment/HRT. This model was developed for changing in concentration of heavy metal especially for cat-ions exchange as it was developed for soil salts exchange balance(Shah, 2013). A common assumption was made that the behavior of cations within the system was similar to each other i.e. Na and Mg behaved similar to Ca. Distribution and concentration of salt within the system changed due to settling and up taking of plants that depended on different HRT. The total balance of salts remained constant throughout the system.

Infiltrating water entered the containers at a rate J (l/m^2/day) with a designated salt concentration C_{in} (molc/l) with salt concentration of equal to finC_{in}(molc/l). A portion of the water evapo-transpirated at rate tj i.e. t represented the infiltrating water fraction that evaporated from the plants leaves and from containers directly. It was assumed that no salts left the container with thee vapotranspirated water. Water moved from the root zone at a rate equal to (l-t) j. The amount of constant water that remained within the container was denoted by V. The total amount of salt within the system solution equaled VC. The salt concentration and composition in the drainage water were assumed to be identical to those in the solution.

For the accumulation period, it was assumed that there was no leakage and T = 1 for the leaching period, there was no evapotranspiration in leaching, hence I = 0, and for all periods the quantity of root zone water V is considered constant. For the root zone, the salt balance was needed which equated the rate of change of the total root zone salt concentration VAC with the salt mass entering into the soil jC_{in}Dt minus the salt mass leaving the soil root zone(1-t) jCΔt,i.e.

$$dC/dt = (jC_{in} - (1-t)jC)/V \qquad (1)$$

It was observed that the gross amount of salt balance was not affected by cation exchange, but condition is that all salt concentrations were presented equally. Also, in Eq. (1), the ratio V/j could be expressed as the time of water turnover in the system. The cycle was started with the concentration duration where an assumption of non-occurrence of leaching was made by setting t = 1, hence

$$dC/dt = jC_{in}/V \qquad (2)$$

The equation (2) was integrated as a function of time, where Co represents concentration at the start of the present cycle:

$$C(t) = C0 + jC_{in}t/V \qquad (3)$$

Which means a monotonic increase of C with respect to time t.

During the leaching period, t =0, hence

$$dC/dt = (j(Ci-C))/V = jC_{in}/V - C/V \qquad (4)$$

Equation (4) was integrated as a function of time, where exponential reduction of the C with respect to time t gave

$$C(t) = b/a + (C0 - b/a)\exp^{-at} \qquad (5)$$

Where b = jC_{in}/v and *a*is equal to j/V which is the reciprocal of turnover time. Leaching periods could be evaluated with equations (3) and (5) successive cycles of accumulation if for each cycle Co is updated. As an alternative a numerical integration of (1) could be made for the same purpose. Where C = Salt concentration in wastewater (WW) solution (molc/l); C_{in} = Salt concentration of incoming wastewater (molc/l); J = Infiltration water that entered the containers ($l/m^2/day$); V = Constant volume of WW in containers (l/m^2); T = Fraction of water that evapotranspirated from the root zone and plant; Co = Salt concentration in the water solution at time = 0 (molc/l)

RESULTS AND DISCUSSION

Electric conductivity (EC): The EC analysis was performed before and after the wastewater treatment with the digital meter. The values of EC in untreated wastewater were from 6.2to6.8. The percentage reduction after wastewater treatment varied from 3 to 26%. The percentage reduction was more in the replications with more HRT (7 days). The percentage reduction had a decreasing trend from a higher HRT to a lower HRT.

Table 1. Electric Conductivity (dS/m) in wastewater at different intervals

Treatment	6 Feb 2018	16 Feb 2018	27 Feb 2018	10 Mar 2018	22 Mar 2018
WW	6.20	6.80	6.50	6.80	6.75
T1 (3-days)	6.01	6.29	6.29	6.32	6.27
T2(5-days)	5.51	5.91	5.93	6.23	6.17
T3(7-days)	5.31	5.20	4.81	5.50	5.55

This percentage reduction in seven days HRT of given treatment was greater as water remained under treatment for more time, which means that the uptake of salts by plants and the settling time of the salts were greater and that effected on each treatment. It was witnessed that the working efficiency of system was higher with higher temperature in the environment. Comparing all the results of different sample data, it was established that the result of third sample date had a higher percentage of reduction. Because before this sampling, the plants had more time to germinate and adapt to the environment after planting.

ANOVA for EC: The statistical analysis (Table 3) was performed using Mini Tab, the statistical software. The ANOVA under RCBD showed that the results were significant for the treatment, but insignificant within the replications.

Table 2. Statistical analysis for Electrical Conductivity

SOV	DF	SS	MSS	F	P	R^2 %
Treatments	2	0.785	0.392	74.362	0.001	
Replications	2	0.027	0.014	2.617	0.180	93.13
Error	4	0.021	0.005			
Total	8	0.833				

The untreated wastewater in the experiment was not within the allowable range of EC. According to IQS, allowable limit of EC must be less than 3 dS/m. In contrast, the range of EC in biologically treated wastewater was not within the permitted IQS.

Sodium Adsorption Ratio (SAR):The SAR analysis was carried outpre and post wastewater treatment using the calculation method using standard SAR equation.The ANOVA under RCBD showed that the results were significant for the treatment, but insignificant within the replications.

Table 3. SAR in wastewater at different intervals

Treatment	6 Feb 2018	16 Feb 2018	27 Feb 2018	10 Mar 2018	22 Mar 2018
WW	32.13	29.09	30.81	31.47	33.68
T1 (3-days)	34.35	30.43	32.60	32.37	34.39
T2(5-days)	37.01	32.85	33.89	32.61	34.87
T3(7-days)	38.42	33.56	35.02	34.52	35.49

Table 4.Statistical analysis of SAR

Source	DF	SS	MS	F-Value	P-Value
Factor	2	91566.45	45783.2	192.07	0.000
Error	6	1401.596	233.603	-	-
Total	8	92968.04	-	-	-

Heavy metals

Fe and Cu: Heavy metal analysis was carried out pre and post waste water treatment using atomic absorption spectrophotometer. The values for heavy metals in untreated wastewater were between 0.03 and 0.9 and the Fe concentration was higher than Cu. The percentage of reduction after wastewater treatment varied between 0 and 92%. The percentage reduction was more in the replications with more HRT (7 days). The percentage reduction was low from greater HRT to smaller HRT.

This percentage of reduction in seven days HRT treatment was greater as water had much time to remain in the container during treatment, this means that the uptake of plants and the settling time of the salts were greater and that affected each treatment results. It was witnessed that the system was more efficient when the ambient temperature was higher in summer i.e. upto 48 C°. Comparing all results from different sample dates, it was observed that the outcomes of the first sampling had higher decrease in percentage. As before the first sample, plants had more time to germinate after planting and adapt to the environment.

For both heavy metals, no statistical analysis was performed as a collective sample was taken for all the replications within one treatment. It revealed that the metal concentration was decreased within a reasonable range, which showed that the wetlands had a better impact on the treatment of the wastewater.

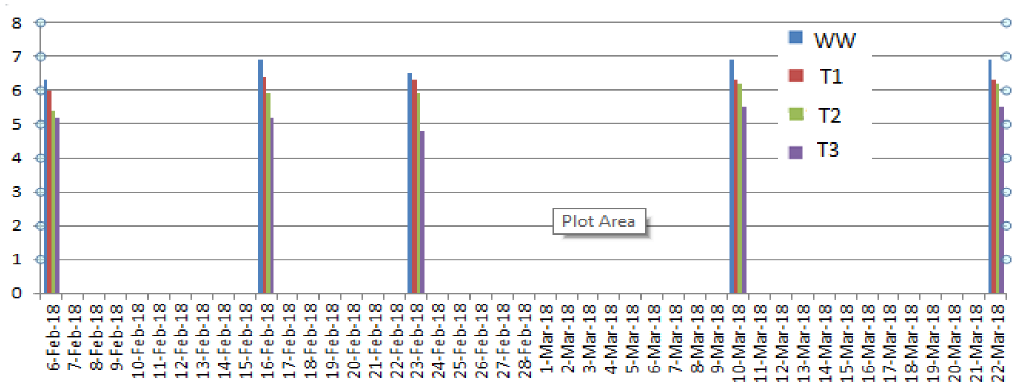

Figure 4. Bar representation of EC

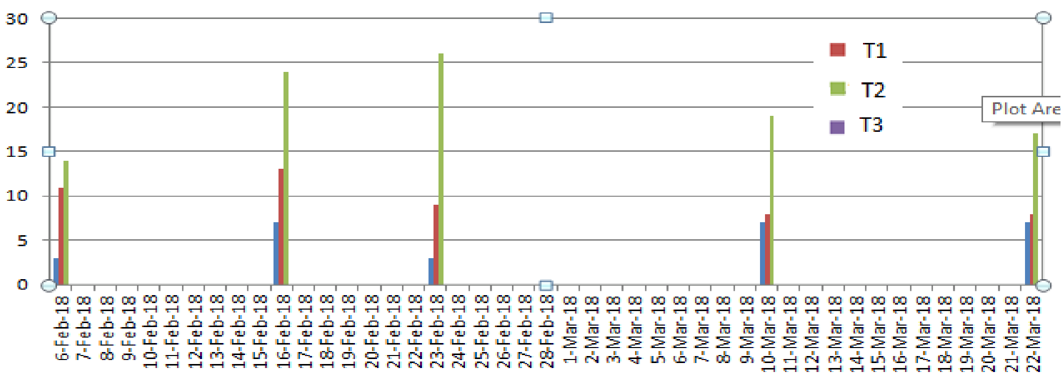

Figure 5. Bar representation of % reduction ofEC

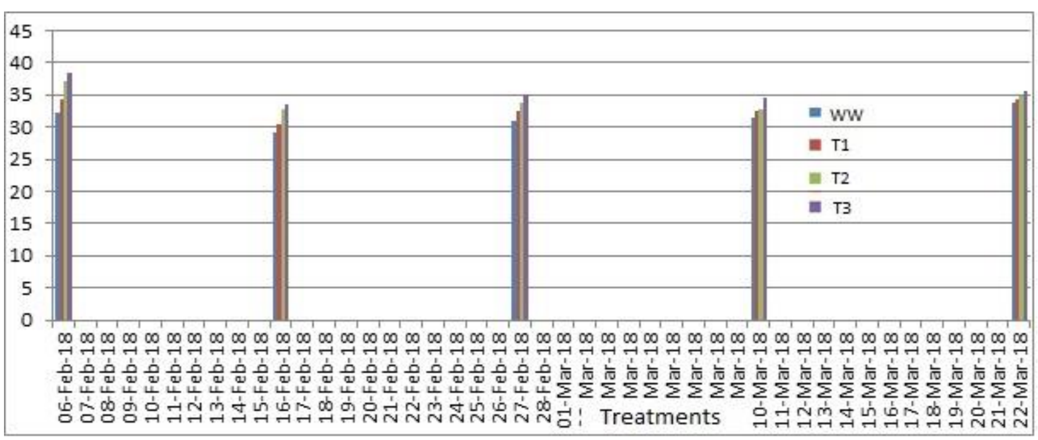

Figure 6.Bar representation of SAR

Table 5. Concentration of Fe (mg/dl) in wastewater at different intervals

Treatment	5 Feb 2018	16 Feb 2018	27 Feb 2018	10 Mar 2018	22 Mar 2018
WW	0.90	0.12	0.12	0.24	0.24
T1 (3-days)	0.90	0.05	0.10	0.14	0.12
T2(5-days)	0.14	0.03	0.08	0.07	0.11
T3(7-days)	0.12	0.01	0.01	0.07	0.03

Wastewater without treatment was found fit for irrigation of crops as the contaminants range was under the allowable range for Fe. According to IQS, allowable range of Fe for crop water must be 5 mg/L. Water containing a density of 20 mg/L could be used for agriculture for shorter duration of time. Whereas for long duration, its concentration should be less than 5 mg/L. (Fipps, 2003). In comparison, bio remediated water was under the permissible range according to IQS which could be used for irrigation for long duration.

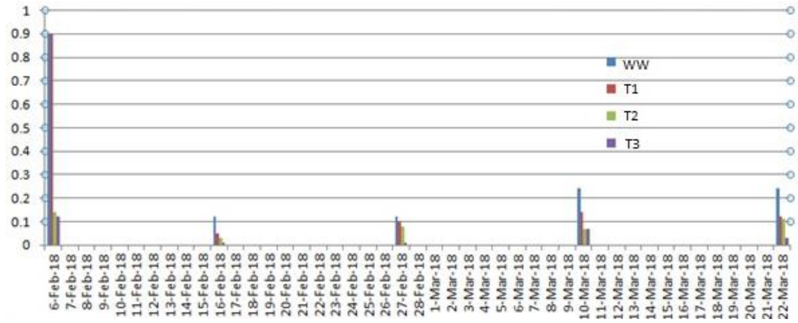

Figure 7. Bar representation of Fe concentration.

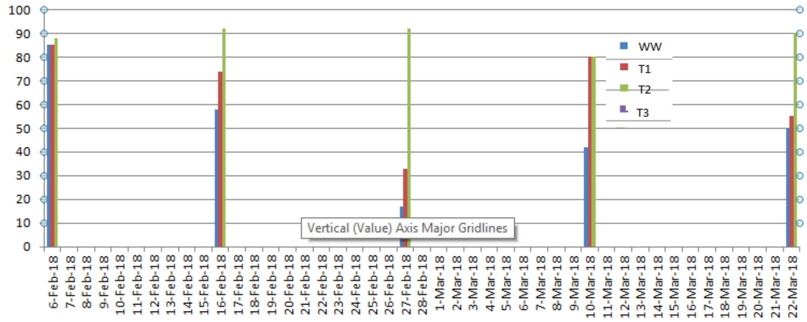

Figure 8. Bar representation of % reduction of Fe concentration

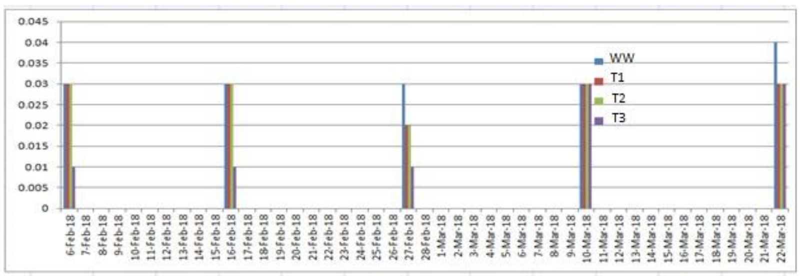

Figure 9. Bar representation of Cu concentration

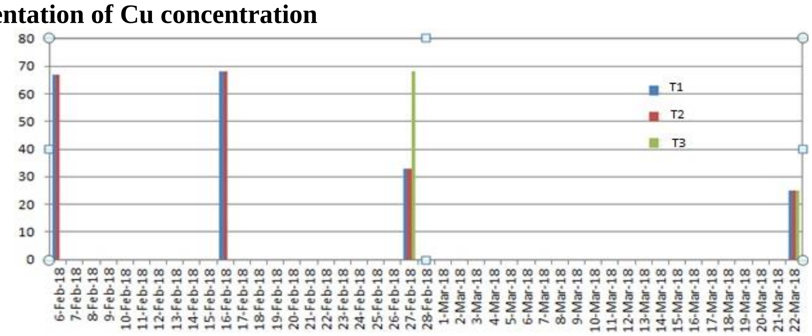

Figure 10. Bar representation of % reduction of Cu concentration

Table 6. Concentration of copper (mg/l) in wastewater at different intervals

Treatment	5 Feb 2018	16 Feb 2018	27 Feb 2018	10 March 2018	22 March 2018
WW	0.03	0.03	0.03	0.03	0.04
T1 (3-days)	0.03	0.03	0.02	0.03	0.03
T2 (5-days)	0.03	0.03	0.02	0.03	0.03
T3 (7-days)	0.01	0.01	0.01	0.03	0.03

Untreated wastewater was found fit for crop irrigation because contaminants range was under the allowable limit for Cu. According to IQS, allowable range of Cu for crop water must be 0.2 mg/L. Water containing a density of 0.2 mg/L Cu could be used for agriculture for small period of time. Whereas for long duration, its concentration should be less than 0.2 mg/L(Fipps, 2003). In comparison, bio remediated water was under the permissible range according to IQS but it showed that by wetland permissible limit for Cu could be

Table 7. Design parameters of CW.

Sr.	Parameters	Literature Value	Selected Value
1	Aspect Ratio (L:W)	> 5	3:1
2	Depth	0.25 m to 0.75 m	1 m
3	Slope	0% to 20%	5%
4	Hydraulic Retention Time (HRT)	3-11 days	7 days
5	Layout and Configuration	3 cells	3 cells
6	Soil and Vegetation	Clay, aggregates, sand, sphagnum peat moss and natural mineral soil Aquatic Plants	sphagnum peat moss and natural mineral soil in a ratio of 25 and 75 water lettuce, duckweed and pennywort
7	Liner material	Polythene, Bentonite Clay, Concrete	Polythene
8	Disinfection Requirement	Chlorine, ultraviolet light	ultraviolet light
9	*Future Expansion*	25 years	25 years

Table 8. Final design of CW.

Sr.	Parameters	Calculations
1	Total discharge of the existing scheme	10.844 cft/min =10.844/35.28 =0.307 m^3 /min
2	Total discharge of the existing scheme in one day	0.307 x 60 x 24 = 442 m^3
3	Total discharge in 7 days	442x 7 = 3095 m^3
4	Assumed working depth	0.5 m
5	Silt pocket provision	0.25 m
6	Free Board provision	0.25 m
7	Total depth = D	1 m
8	Area of Wetland = V/D	3095/1
10	Area = Length x Breadth= A = L x B	A = 3095 m^3
11	Aspect Ratio	3:1
12	L	3B
13	A = 3B x B = 3 B^2	75.95 = 3 B^2
14	B	32.13
15	L = 32.13X 3 = 96.37 m	96.37 m
16	Estimated size of wetland	96.37 x 32.13 x 1
17	Add factor of safety for L & B	= 10%
18	Size of CW	106.03 x 35.34 x 1
19	Say	106 m x 35 m x 1 m

obtained and this water could be used for irrigation for long duration.

Modeling Results (Numerical Equation Approach): A model was developed to compare the modeled and observed values by using "R" software. A numerical equation was developed to model the leaching of salts in soil with passage of time. It was assumed that various processes take place in the wetland. Salts leached down or taken up by plants roots as water stayed in ponds according to their designed HRT. While developing this model it was also assumed that there was no loss of water through leakage and evapotranspiration. The leaching equation is reproduced below:

$$C(t) = \frac{b}{a} + (C_0 - \frac{b}{a})\ \exp^{-a} \quad (5)$$

Equation had exponentially decreasing factor that was dependent on time (t) which was HRT. Some other parameter like HRT, flux rate, average rate of incoming salts, constant volume of water that remained in the ponds and losses were also considered while developing this model. A loop was created in model that the final concentration value of previous pond becomes the first value of concentration for the next pond and made comparison between observed and modeled values.

It was observed that modeled values stayed at the initial concentration value of salts and other parameters. So, it could be said that only those parameters that were considered in this modeled equation were not enough for wetland model. Other parameters like evapotranspiration, effect of temperature, types and properties of selected wetland plants, plants salts uptake rate through roots and type of wastewater should also be considered. Only HRT and fluxes of concentration were not enough for this model. But it could be said that the first model values were close to some extent of our observed values. By adding additional numerical equation, model results could be enhanced.

***Modeling results (Observed Data Equations Approach)*:** The second approach was performed using the observed data. Based on the R^2 values of each data, an equation was developed and the graphs were plotted between the observed and modeled values to verify the relationship between the observed and modeled values. The values that remain above the "abline" were predicted to be exaggerated, and the values below that line are less predicted. As the values approached the line, it was concluded that these values are more accurate than the modeled values.

***CW Design*:**A sewerage scheme had been completed by WASA Lahore in Shadbagh town in the year 1999. Data about this scheme had been collected from WASA which is given below. On the basis of thesedata, the results of the sample testing and their modeling, following design of CW is recommended for the treatment of wastewater of the study area in place of traditional treatment plant.

Design Parameters of CW Considered in this Study: Based on the previous studies for various types of CWs, the results received from the testing of the samples and their modeling in the present study following parameters were considered in the design of CW.

Conclusions: Constructed Wetland is a technology in which wastewater can be treated using the aquatic plants called macrophytes after using engineering technique with proper management. Wastewater comprises the concentration of heavy metals tend to deteriorate the ground water, soil and health of humans. Using the wetland, the heavy metal concentration in waste water can be decreased. There is a tendency of heavy metals to continue for long time. These heavy metals can be transferred from one body to other. Wetland plants have the quality to uptake these metals. After up-taking of salts, these plants can be disposed off safely. Water lettuce has the ability to remove smell from wastewater. During the process, a production of microbial colony around its roots takes place which degrades sludge and treats wastewater. But on the other hand, it has less ability of circulation of O_2 in its roots. To avoid this problem, water lettuce plant was planted in first pond of wetland. HRT is a decisive factor which has a direct impact on the wetland efficiency to treat wastewater. Efficiency depends heavily on HRT i.e. giving more time to plants for treatment of wastewater will improve quality of wastewater. In this experiment the third treatment was provided with Hydraulic Retention Time (HRT) of 7 days during the experiment. It showed best results to treat wastewater within the permissible limits. Hence optimum HRT for this experiment was 7 days.

Recommendations; Conventional treatment of wastewater is too much costly due to incurring expenditure on its infrastructure, machinery and operation & maintenance. In comparison CWs are much cheap, hence these are recommended for construction to treat wastewater. The wastewater disposal points are the best places for wastewater treatment. These areas have huge collection points of wastewater in the shape of ponds. These ponds can be converted into CWs with little alteration after using appropriate engineering techniques and proper management. Various type of CW must be built and the efficiency of these wetland be compared with each other and the wetland producing good results be encouraged for its construction on mass scale. Other plants like Duck Weed, Typha and Cyper Papyrus etc. should be tried as an alternative during treatment to treat wastewater. Wetland sites can be changed as places of visit or garden and treated wastewater can be used for crops irrigation as it is within the permissible limits of water standards. Government should encourage the construction of wetlands and the wastewater treatment with the help of constructed wetland after taking necessary steps.

REFERENCES

Adeniran, A.E., A. Aina and O. Oshunrinade. 2014. Performance characteristics of pollutants along the longitudinal profile of a subsurface flow constructed wetland domestic sewage treatment plant in the University of Lagos, Nigeria.Water. Resour. Prot. 6:104.

Ahmad, M. and U. Farooq. 2010. The state of food security in Pakistan: Future challenges and coping strategies. Pak. Dev. Rev.94:903-923.

Ahmed, F. 2018. Water scarcity.

Akhtar, M. and Z. Tang. 2013. Identification of contamination sources and TDS concentration in groundwater of second biggest city of Pakistan.Int. J. Environ. Sci. 4:341-345.

Alcalde-Sanz. L. and B.M. Gawlik. 2017. Minimum quality requirements for water reuse in agricultural irrigation and aquifer recharge - Towards a water reuse regulatory instrument at EU level, EUR 28962 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-77176-7, doi 10.2760/887727, PUBSY No.109291.

Arlosoroff, S. 2007. Wastewater management, treatment, and reuse in Israel. Wastewater reuse–risk assessment, decision-making and environmental security.NATO Science for Peace and Security Series. Springer, Dordrecht. 55-64.

Ashraf, M.A., M.J. Maah, I. Yusoff and K. Mehmood. 2010. Effects of polluted water irrigation on environment and health of people in Jamber, District Kasur, Pakistan. Int. J. Sci: Basic. Appl. 10:37-57.

Blumenthal, U.J., E. Cifuentes, S. Bennett, M. Quigley and G. Ruiz-Palacios. 2001. The risk of enteric infections associated with wastewater reuse: the effect of season and degree of storage of wastewater. T. Roy. Soc. Trop. Med. H. 95:131-137.

Bogardi, J.J., D. Dudgeon, R. Lawford, E. Flinkerbusch, A. Meyn, C. Pahl-Wostl, K. Vielhauer and C. Vörösmarty. 2012. Water security for a planet under pressure: interconnected challenges of a changing world call for sustainable solutions. Curr. Opin. Env. Sust. 4:35-43.

Bos, R., R. Carr and B. Keraita. 2010. Assessing and mitigating wastewater-related health risks in low-income countries: An introduction. Wastewater irrigation and health: Assessing and mitigating risk in low-income countries.International Water Management Institute (IWMI). Pp.29-47.

Calheiros, C.S., A.O. Rangel and P.M. Castro. 2009. Treatment of industrial wastewater with two-stage constructed wetlands planted with Typha latifolia and Phragmites australis. Bioresour. Technol. 100:3205-3213.

Connor, R. 2015. The United Nations world water development report 2015: water for a sustainable world, UNESCO Publishing. Pp. 1-139.

Cooper, R. 2018. Water, sanitation and hygiene services in Pakistan.

Cosgrove, W.J. and D.P. Loucks. 2015. Water management: Current and future challenges and research directions.Water. Resour. Res. 51:4823-4839.

Domininguez-Patiño, M.L., A. Rodríguez-Martínez and L.A. Jasso-Castillo. 2012. Design and Implement a System of Wastewater Treatment Based on Wetlands. JSC. Info.Pp.6-11.

Eberstadt, N. 2010. The demographic future: What population growth—and decline—means for the global economy. Foreign Affairs.89.54-64.

Flores, O., A. Jimenez and A. Perez-Foguet. 2013. Monitoring access to water in rural areas based on the human right to water framework: A local level case study in Nicaragua.Int. J. Water. Resour. D. 29:605-621.

Ghazy, M.M., W.M. Senousy, A.M. Aatty and M. Kamel. 2008. Performance evaluation of a waste stabilization pond in a rural area in Egypt. Am. J. Environ. Sci. 4:316-325.

Haddeland, I., J. Heinke, H. Biemans, S. Eisner, M. Flörke, N. Hanasaki, M. Konzmann, F. Ludwig, Y. Masaki and J. Schewe. 2014. Global water resources affected by human interventions and climate change. Proc. Natl. Acad. Sci. 111:3251-3256.

Han, S., Z. Chen and F. Zhou. 2014. Three-Dimensional Numerical Model to Evaluate the Suspended Solid Removal in Surface Flow Constructed Wetland.Int. Congress on Env. Modeling and Software. 78: 2131-2138.

Hiley, P.D. 1995. The reality of sewage treatment using wetlands. Water. Sci. Technol. 32:329-338.

Kadlec, R.H., R. Knight, J. Vymazal, H. Brix, P. Cooper and R. Haberl. 2017. Constructed wetlands for pollution control, IWA publishing. London.

Karczmarczyk, A. and G. Renman. 2011. Phosphorus accumulation pattern in a subsurface constructed wetland treating residential wastewater. Water. 3:146-156.

Khan, M.A., S.S. Shaukat, O. Hany and S. Jabeen. 2010. Irrigation of sorghum crop with waste stabilization pond effluent: growth and yield responses. Pak. J. Bot. 42:1665-1674.

Leahy, S. 2018. From Not Enough to Too Much, the World's Water Crisis Explained. National Geographic.com

Levy, D., W.K. Coleman and R.E. Veilleux. 2013. Adaptation of potato to water shortage: irrigation management and enhancement of tolerance to drought and salinity. Am. J. Potato. Res. 90:186-206.

Mandal, D., P. Labhasetwar, S. Dhone, A.S. Dubey, G. Shinde and S. Wate. 2011. Water conservation due to greywater treatment and reuse in urban setting with specific context to developing countries. Resour. Conserv. Recy. 55:356-361.

Mangunwardoyo, W., T. Sudjarwo and M.P. Patria. 2013. Bioremediation of effluent wastewater treatment plant Bojongsoang Bandung Indonesia using consortium aquatic plants and animals. Int. J. Res. Rev. Appl. Sci. 14:150-160.

Mekonnen, M.M. and A.Y. Hoekstra. 2016. Four billion people facing severe water scarcity. Sci. Adv. 2:e1500323.

Murtaza, G. and M.H. Zia. 2011. Individual's capacity development on the safe use of wastewater in agriculture in Pakistan. Institute of Soil and Environmental Sciences, University of Agriculture, Faislabad.

Murtaza, G. and M.H. Zia. Wastewater production, treatment and use in Pakistan. Second Regional Workshop of the Project 'Safe Use of Wastewater in Agriculture.Pp. 16-18.

Nasir, A., C. Arslan, A. Sattar and M.A. Khan. 2012. Physical analysis of groundwater at thickly populated area of Faisalabad by using GIS. Pak. J. Agri. Sci. 49:541-547.

Naz, M., S. Uyanik, M.I. Yesilnacar and E. Sahinkaya. 2009. Side-by-side comparison of horizontal subsurface flow and free water surface flow constructed wetlands and artificial neural network (ANN) modelling approach. Ecol. Eng. 35:1255-1263.

Oliveira, S.C. and M. Von Sperling. 2011. Performance evaluation of different wastewater treatment technologies operating in a developing country. J.Water. Sanit. Hyg. De. 1:37-56.

Organization, W.H. 2017. Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines. Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines.

Pakistan Econimic Survey2017. Econimic advisors wing finance division Government of Pakistan Islamabad. (www.finance.gov.pk).

Pakistan Econimic Survey 2018. Econimic advisors wing finance division Government of Pakistan Islamabad. (www.finance.gov.pk).

Putra, R.S., F. Cahyana and D. Novarita. 2015. Removal of lead and copper from contaminated water using EAPR system and uptake by water lettuce (*Pistia stratiotes* L.). Procedia chem. 14:381-386.

Qureshi, D.A. and A.H. Sayed. 2014. Situation analysis of the water resources of Lahore establishing a case for water stewardship. WWF-Pakistan and Cleaner Production Institute (CPI), Lahore, Pakistan.

Rana, S. 2017. 6th census findings: 207 million and counting. The Express Tribune.

Raschid-Sally, L. and P. Jayakody 2009. Drivers and characteristics of wastewater agriculture in developing countries: Results from a global assessment, IWMI.

Salik, K.M., S. Ishfaq, F. Saeed, E. Noel and Q. Syed 2015. Pakistan: country situation assessment, Sustainable Development Policy Institute.

Samsó, R., J. García, P. Molle and N. Forquet. 2016. Modelling bioclogging in variably saturated porous media and the interactions between surface/subsurface flows: Application to Constructed Wetlands. J. Environ. Manage. 165:271-279.

Scheierling, S.M. 2011. Assessing the direct economic effects of reallocating irrigation water to alternative uses: concepts and an application, The World Bank. Washington, DC, USA.

Shah, S.H.H. 2013. Modeling the effects of saline groundwater and irrigation water on root zone salinity and sodicity dynamics in agro-ecosystems. Water Resour. Res. 47:1-47.

Shojaei, P., M. Karimlou, J. Nouri, F. Mohammadi, H.M. Afzali and A.S. Forouzan. 2014. Ranking the effects of urban development projects on social determinants of health: health impact assessment. Glob. J. Health Sci. 6:183-195.

Un-Habitat 2010. State of the world's cities 2010/2011: bridging the urban divide. Earthscan.

Van Der Bruggen, B. 2010. The global water recycling situation. Sustain. Sci. Eng. 2:41-62.

Vervoort, R.W. and S.E. Van Der Zee. 2009. Stochastic soil water dynamics of phreatophyte vegetation with dimorphic root systems. Water Resour. Res. 45:1-13.

Volodymyr, T., A. Sirajuddin and P. Viktor. 2007. Modelling constructed wetland system performance. Ecol. Model. 205:355-64.

Vymazal, J. 2010a. Constructed wetlands for wastewater treatment. Water. 2:530-549.

Vymazal, J. 2010b. Constructed wetlands for wastewater treatment: five decades of experience. Environ. Sci. Technol. 45:61-69.

Vymazal, J. 2014. Constructed wetlands for treatment of industrial wastewaters: a review. Ecol. Eng. 73:724-751.

Wichelns, D. and P. Drechsel. 2011. Meeting the challenge of wastewater irrigation: economics, finance, business opportunities and methodological constraints. Water Int. 36:415-419.

Yalcuk, A. 2013. Modeling Different Types of Constructed Wetlands for Removing Phenol from Olive Mill Wastewater using an Artificial Neural Network. Ekoloji Dergi.88:28-35.

Zheng, Y., X. Wang, J. Xiong, Y. Liu and Y. Zhao. 2014. Hybrid constructed wetlands for highly polluted river water treatment and comparison of surface-and subsurface-flow cells. J. Environ. Sci.. 26:749-756.

Zidan, A.R.A., M.M. El-Gamal, A.A. Rashed and M.a.a.E.-H. Eid. 2015. Wastewater treatment in horizontal subsurface flow constructed wetlands using different media (setup stage). Water Sci. 29:26-35.

[Received 25 Sept 2019: Accepted 07 March 2020: Published (online) 08 June 2020]