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RESEARCH PAPER

Technical Design of Constructed Wetland unity for Municipal Wastewater Treatment and Reuse for a Green Space Irrigation: Case of the new City of Ouled Djellal –Algeria

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Abstract

This work investigates the possibility of using constructed wetland system for the management of municipal wastewaters with reuse strategies for the irrigation of landscapes in Ouled Djellal city of Biskra, Algeria. The design of this system was based on the characteristics (volume and physico-chemical properties) of wastewaters and the urban plan of the studied city. Results showed that studied effluent is easily biodegradable with COD/BOD5 of 1.84 (< 3), BOD5 (325 - 365 mg/L), COD (620-644 mg/L) and TSS (120-250mg/l). The peak of raw wastewater flow was found to be 32.4 m^3 /h, which was used for the calculation of drip network for the landscape irrigation. The selected variant for the configuration of the CW system is HF-VF-HF, which occupies an area of 11.580 m^2 and will reduce significantly the water pollution. The treated wastewater will be reused for the irrigation of landscapes via the dimensioned drip network. Results of this study showed that the proposed design for the system (treatment and reuse) would be effective in reducing pollution in the urban environment by ensuring possibility of the reuse of the treated water for irrigation. This gives also a great opportunity for using this strategy in small neighborhoods in other cities.

Keywords: constructed wetlands, wastewater, irrigation, green space.

INTRODUCTION

In recent modern times, water, energy, and food security are under increasing demand from population around the world. Water is fundamental for life needs and the biochemistry of living organisms. However, the accelerating population growth, urbanization, industrial activity, climate change, and globalized economy have led to many environmental disturbances in particular pollution of water resources (Sherbinin et al., 2007). In fact, untreated sewage and agricultural runoff continue to be a worldwide problem. Constructed wetlands are increasingly receiving attention for wastewater treatment including sewage, industrial and agricultural wastewaters and landfill leachate (Vymazal, 2005; Vymazal, 2010).

Constructed wetlands (CWs) are efficient in removing organics through microbial degradation and settling of colloidal particles. In addition, pollution is removed under more controlled conditions to produce an acceptable quality of water for either reuse or discharge (Vymazal, 2005; Saeed & Sun, 2012; Mehta et al., 2015). CWs systems have very low operation and maintenance costs, and they have a strong potential for application in a small community. In

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addition, various types of CWs may be combined in order to achieve more wastewater treatment efficiency (Tuncsiper, 2009; Ghrabi el al.,2011). These hybrid systems comprise most frequently vertical flow (VF) and horizontal flow (HF) systems that produce an effluent low in BOD, which is fully nitrified and partly denitrified with much lower total-N concentrations (Cooper, 1999; Cooper, 2001).

Ouled Djellal counts among the most important old cities of the south-east region of Algeria by its cultural and religious dimension. Water is a serious concern in this city due to the local semi-arid climate and limited fresh water resources. Indeed, all the green spaces of the city of Ouled Djellal suffer from the scarcity of water, and are mostly irrigated by tanker trucks of the town. Currently, the choice of plants species and the design of CWs unity present an economic and environmental challenge in research. Several studies have also showed the high efficiency of CWs system grown with various type of plants under arid conditions (Yahiaoui et al.,2020; Bensmina et al.,2014; Bebba et al., 2019; Saad et al., 2016).

Growth media provide not only physical support for plant growth but also additional sites for biofilm growth and the adsorption of nutrients and promote the sedimentation and filtration of pollutants (Li et al., 2010; Priya et al., 2013). Gravel is the most commonly used media in CW (EPA, 1993). The combination of gravel-sand treatment system has been found to be useful to efficiently reduce contaminants from urban wastewater at minimal cost (Tlili et al., 2021).

However, there is very little information in the existing literature regarding the integration of small CWs unities in the urban environment of municipalities. Therefore, this work investigate the design of CW pilot plant combining a sub-surface horizontal and vertical flow filters to treat wastewater and irrigate the green space at Ouled Djellal city. The wastewater characteristics, climate of region, water policies, demands of water, and development plan of the studied city

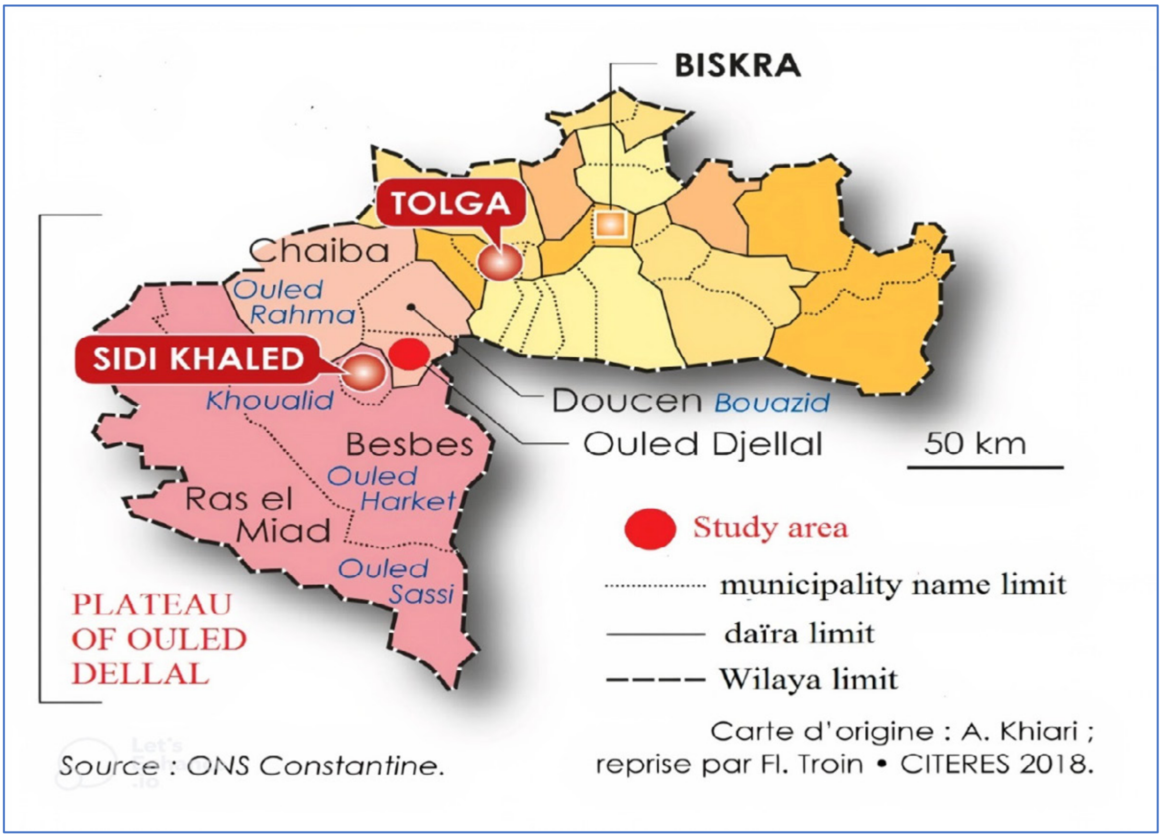

Fig 1. Location of Ouled Djellal municipality (source: ONS Constantine, CITERES 2018)

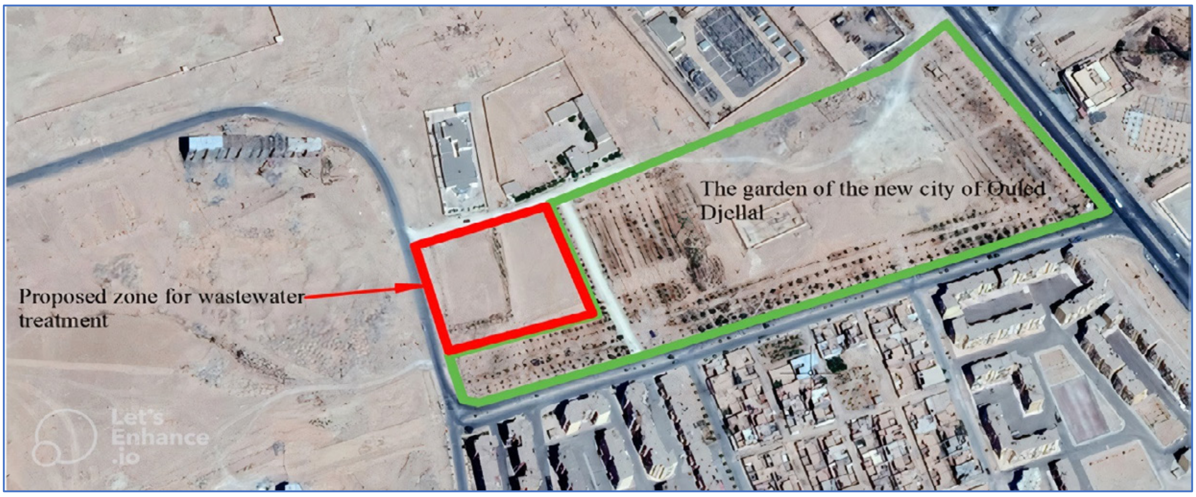

Fig 2. Location of the new city of Ouled Djellal and the proposed zone for wastewater treatment plant (Source Google Earth)

were taken into count. A design model for a water treatment plant for a small neighborhood at Ouled Djellal city was detailed herein.

MATERIALS AND METHODS

Geographical situation

The present study was conducted in Ouled Djellal city (Biskra region- Algeria-). The city covers a total area of 326.6 km^2 and the agriculture is the main source of income in the region. This city is experiencing a real water shortage due to climatic conditions and the lack of facilities available for the treatment and reuse of water.

The studied garden has an area of 3 hectares with 900 trees. The green colored part represents the boundary of the garden and the colored red part corresponds to the surface reserved for the proposed treatment zone (Fig.2). It is worth noting that there is no water and irrigation network for the garden while a significant amount of wastewater reached the garden from the new city. This wastewater is discharged by a sewerage system collector.

Climate overview

The studied region has a hyper-arid of Saharan-type climate. The observed climate datasets in the study area were precipitation, temperature, evaporation, relative humidity, wind. Table 1 summarizes the meteorological data for the year 2018.

Data of Table 1 revealed that the average annual temperature was 22.9 °C with average minimum and maximum temperatures of 7.5 °C (February) and 43.5 °C (July). The highest maximum of relative humidity during the year was 67% (December) while the lowest minimum of relative humidity was 26% (July). The highest maximum net radiation during this year was 27.8 MJ/m^2(June) while the lowest minimum net radiation was 10.5 MJ/m^2(December). The average annual rainfall was approximately of 10.76 mm. The highest maximum wind speed during the year was 6.2 m/s (March) while the lowest minimum wind speed was 3.1 m/s (September). The annual mean of the crop evapotranspiration (ETc. mm/year) of the studied site was 5.62 ± 3.0 (Table 2). The highest value was recorded in July (10.7 mm) due to the highest net radiation and high temperature whereas the lowest value was observed in December (2.52 mm). The variation in evapotranspiration rates reflects the high change of weather parameters in the studied area. Accordingly the low relative humidity high temperatures and high wind increased the evapotranspiration during the dry season (Doorenbos & Pruitt, 1977; Huo et al., 2013).

Table 1. Meteorological data and evapotranspiration of Ouled Djellal city, Algeria in 2018 (NMO. 2018).

Year	Month	Temperature (°C)		Average temperature (°C)	Humidity (%)	Rainfall (mm)	Wind (m/s)
		T_{Max}	T_{Min}				
2018	January	19.2	9	13.7	53	0.2	5
	February	17.6	7.5	12.2	57	8	4.7
	March	22.9	12.4	17.4	46	12.9	6.2
	April	28.3	16.3	22.2	42	0.4	5.4
	may	30.8	19.5	24.9	47	49.4	4.9
	June	36.9	23.9	30.7	35	0	4.6
	July	43.5	30.5	37.1	26	0	3.9
	August	37.8	26.3	31.8	43	2.4	3.2
	September	36.5	24.9	30.3	44	16.9	3.1
	October	27.6	17.6	22.1	56	36.8	4.1
	November	22	11.8	16.4	59	1.2	4.3
	December	19.2	9.9	17	67	1	4.2
	Average	**28.53**	**17.47**	**22.9**	**47.92**	**10.76**	**4.47**

Table 2. Evapotranspiration data (mm/day) of Ouled Djellal city, Algeria in 2018 (NMO. 2018).

Month	T_{Max}	T_{Min}	Humidity	Wind	Sunshine	Radiation	EToPenman	ETcrop
	°C	°C	%	m/s	hours	$MJ/m^2/day$	mm/day	mm/day
January	19.2	9.0	53	5.0	7.3	11.4	2.81	2.25
February	17.6	7.5	57	4.7	6.7	13.0	3.3	2.81
March	22.9	12.4	53	6.2	6.7	15.9	5.11	4.60
April	28.3	16.3	50	5.4	8.4	20.7	6.68	6.35
may	30.8	19.5	47	4.9	9.7	24.0	7.69	7.69
June	36.9	23.9	37	4.6	12.0	27.8	9.97	9.97
July	43.5	30.5	34	3.9	10.1	24.7	10.7	10.70
August	37.8	26.3	43	3.2	10.0	23.3	8.17	8.17
September	36.5	24.9	52	3.1	8.5	18.9	6.63	5.97
October	27.6	17.6	61	4.1	7.6	14.8	4.68	3.98
November	22.0	11.8	60	4.3	7.1	11.6	3.47	2.95
December	19.2	9.9	67	4.2	7.2	10.5	2.52	2.02

Water requirements

Crop water requirement corresponds to the level of evapotranspiration (ET_0) of a healthy crop growing in a parcel of land greater than one hectare under optimal soil conditions. These conditions consist mainly of sufficient fertility and moisture to reach the potential production of the crop in the environment (Doorenbos & Pruitt, 1977). The evapotranspiration (ETcrop) was calculated using the Penman formula as specified by the FAO protocol (Pereira et al., 2015).

$$ET_{crop} = K_c \times ET_0 \tag{1}$$

where: Kc is the crop coefficient. It is the ratio of the crop ETcrop to the ET_0. The calculation is done by the software Cropwat 8.

The crop coefficient (Kc) values for well-watered mature palms are in the range of 0.8–1.0 (Doorenbos & Pruitt, 1977). In the present study, Kc was found to be 1.0, so the water requirement of the trees is 10.7 mm/day (Table 2) corresponding to a flow rate of 32.4 m^3/h for a watering period of 10 hours with a drip irrigation system of 12 L/h. However, it should be noted that the current domestic flow of wastewater from the city of Ouled Djellal is estimated at 99.10 L/s. and approximately 9 % of this quantity can be used to irrigate the garden of the new city of Ouled Djellal.

Sampling and analysis of wastewater

In this study, two sampling periods were considered (in 18/03/2018 and in 08/01/2019). The samples were taken at the secondary wastewater collector, which gathers all the raw effluents of the new city of Ouled djellal. The collected samples were transported to the laboratory in a cooler (4°C).

All analyzes and measurements required to quantify organic pollutants were standardized according to Rodier et al., (2005). The parameters measured in situ were pH, temperature, and electrical conductivity of water using a WTW model 7110 multi-parameter analyzer. Other parameters analyzed in laboratory such as five-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD) and a total suspended solid (TSS). The BOD_5 was determined by the instrumental method by using the BOD meter enclosure adapted to the incubation's conditions and equipped with a WTW stirrer type LOVIBOND. Oxitop Is6 (temperature maintained at 25 °C for 5 days). The COD was measured by acid oxidation with potassium dichromate in the presence of iron and ammonium sulfate at 140 °C using a heating block equipped with 16 sample positions type WTW. CR2200. The suspended solids were determined by filtration of a volume of wastewater on cellulosic filters (0.45 µm mesh). The other parameters were analyzed by colorimetric dosage.

Design of drip irrigation system

Drip irrigation is one of the localized irrigation techniques (micro-irrigation) that involves providing each individual plant or tree with the exact amount of water it needs. It depends on soil types, specificities of the climate without considerable runoff. High-frequency application of micro-irrigation over a long period of time can maintain an optimum moisture level in the root zone (Daniel & Pierre, 1980; Kang et al., 2010). The drip irrigation network was sized at flow rates of 32.4m^3/h for a watering time of 10 hours. The diameters of the ramps, ramp doors, and main pipe were 11mm to 18mm, 30mm to 50mm, and 63mm to 90mm, respectively.

Design of constructed wetlands unity

In this study, a hybrid-constructed wetland for the treatment of wastewater of the new city of Ouled Djellal was proposed. The system was composed from Horizontal and vertical surface flow wetland.

Horizontal surface flow wetland

The horizontal flow filter of the constructed wetland was dimensioned by using the following formula (Reed et al., 1995) :

$$A_s = \frac{Q}{K_T \times h \times n} \ln\left(\frac{C_e}{C_s}\right) \tag{2}$$

Where: Q (m^3/day) is the average flow rate through the filter. C_s is the concentration of pollutant at outlet effluent (mg/L). Ce is the concentration of pollutant in the raw wastewater (mg/L), n is the porosity (percent. expressed as decimal fraction), h is the depth of the wetland (m), and K_T represents rate constant (day^{-1}).

The effluent BOD_5 from the constructed wetland was determined using the following equation:

$$\ln\left(\frac{C_e}{C_s}\right) = K_T \times t \tag{3}$$

The rate constant K_T can be given as follow:

$$K_T = K_R \times \theta^{(T_W - T_R)} \tag{4}$$

Where: K_R is constant at the reference temperature. θ is coefficient of temperature. T_R is the temperature reference and T_R is the temperature of the humid zone.

Value of K_R, T_R and θ was determined by (Reed et al., 1995) as mentioned in Table 3:

The hydraulic residence time (HRT) was calculated using the following equation (Reed et al., 1995):

Table 3. Values of temperature constants (K_R, T_R and θ).

Parameter	**T_R (°C)**	**K_R (day^{-1})**	**θ**
Value	20	1.104	1.06

$$t = \frac{L \times W \times n \times h}{Q} \tag{5}$$

Where: n is the effective porosity of media, L (m) is the length of bed, W (m) is the width of bed (m), h (m) represents the average depth of liquid in bed (m), Q (m^3/d) is the average flow through the bed.

Vertical surface flow wetland

The dimensions of filter should be determined according to the need for oxygen (Von Felde & Kunst, 1997). The maximum oxygen transfer rate of vertical surface flow wetlands was considered to be $30gO_2/m^2.d^{-1}$ (Cooper, 1999; Vymazal, 1998) and the area needed was calculated as follow (Noorvee et al., 2005).

$$A = \frac{DO}{VA} \times 1.25 \tag{6}$$

Where: A (m^2) is the area of bed. OD is the oxygen demand of the wastewater entering the wetland system ($gO_2.d^{-1}$). VA represents the aeration potential of a VF wetland ($30gO_2m^{-2}d^{-1}$).

RESULTS AND DISCUSSION

Wastewater characteristics

Results of physico-chemical analysis of the raw wastewater from the new city of Ouled Djellal are shown in (Table 4). The average temperature values varied between15.1 °C and 21 °C. These results showed a seasonal difference in temperature between Mars and January. The average

Table 4. Physico-chemical analysis of the raw wastewater from new city of Ouled Djellal.

Parameters	Unit	1st sampling (18/03/2018)	2nd sampling (8 /01/ 2019)	Maximum allowable concentration
T°	Degree Celsius	21	15.1	30
PH	-----	7.86	8.41	6.5-8.5
Electrical conductivity (EC)	(µs/cm)	2900	3350	3000
Turbidity	NTU	415	520	-----
Dissolved oxygen (DO)	(mg/L)	0.06	0.02	-----
Nitrate	(mg/L)	0.872	5.37	30
Sulphate	(mg/L)	0.65	0.5	-----
Phosphate	(mg/L)	0.16	0.4	-----
BOD_5	(mg/L)	325	365	30
COD (mg/l)	(mg/L)	644	620	120
TSS	(mg/L)	250	120	30
Total nitrogen (NTK)	(mg/L)	-	22.4	30
Fer	(mg/L)	1.5	0.8	3

temperature recorded in this study was below the limit value of the Algerian standards (JORA, 2006) and it was also below the permitted value for water intended for irrigation (35 °C).

The pH value of raw wastewater was between 6.5 and 8.5. which meet the Algerian standards (JORA, 2006; APHA, 1989).

The average values of the electrical conductivity (EC) ranged between 2900 µs/cm and 3350µs/cm which means that wastewater display a very important mineralization (APHA, 1989).The results exceed the upper limit recommended by the Algerian standards (JORA, 2006).These results are higher to that recorded by (Mamine et al.,2020). The authors studied three sites and obtained 1100 to 1668µs/cm for site 1, 1040 to 1311µs/cm for site 2, and 1239 to 1500µs/cm for site 3. According to Franck (2002), any pollutant discharge is accompanied by an increase in the electrical conductivity.

The turbidity of water is due to the presence of finely divided and suspended solids including clay, silt, grains of silica, organic matter, etc. The determination of the level of these particles measures the degree of turbidity (Schroeder, 2003). In the present study, the values of turbidity varied between 415 and 520 NTU which means that this wastewater is highly turbid. The results are consistent with the study carried out by Gnagne et al. (2015), who studied eight stations and reported values ranging between 105±49.7 to 471.5±171 NTU. The concentration of dissolved oxygen varied between 0.02 and 0.06 mg/L, these values being less than 1 mgO_2 per liter indicate an anaerobic state (Muller & Weise, 1987). This can be explained by the high organic compounds in the raw wastewater. These values are very lower to that reported previously (Yahiaoui et al., 2020; Zegait & Boualem, 2018).

In this study, very low levels of nitrate were recorded in the studied raw wastewater. Values varied between 0.87 mg/l and 5.37 mg/l. The obtained results are in accordance to the limit recommended by (WHO, 2011) and (FAO, 1985) for irrigation water. In addition, these results are in agreement with findings of Zegait and Boualem (2018) who found values ranging between 0.2mg/l and 4mg/l.

The studied wastewater is characterized by low levels of orthophosphate and varied between 0.16 mg/l and 0.4 mg/l. These values were in accordance with national standards (<2 mg / l) (JORA, 2006) and the limit recommended by FAO for irrigation water (FAO, 1985). Our results are lower to findings reported in more recent studies (Mamine et al., 2020; Zegait & Boualem, 2018).

BOD_5 measures the amount of molecular oxygen used by microorganisms during an incubation period of 5 days at 20 °C to decompose the organic matter dissolved or in suspension contained in one liter of water. The studied wastewaters showed high BOD_5 values which ranged from 325 to 365 mg O_2/l. Accordingly, BOD_5 values were very higher to Algerian discharge standards (JORA, 2006). Similar results were reported by Hamdi (2012) with values varying between 340 mg/l and 490 and Majdy et al. (2015) who obtained an average value of 340 mg/l. As well, our results are consistent with those found by Yahiaoui et al. (2020) for urban wastewater in arid region (Algeria), Whereas, the obtained results are very higher compared to those recorded by Mamine et al. (2020).

COD assess the concentration of organic or mineral matter dissolved or suspended in water through the amount of oxygen necessary for their total chemical oxidation. In the present study, COD values varied between 620 mg O_2/l and 644 mg O_2/l. These exceed the value recommended by Algerian standards (90 mg/l) (JORA, 2006). The obtained results are in agreement with that obtained in other previous studies. In fact, Hamdi (2012) reported COD values varying between 595 mg/l and 672 mg/l in the region of Ouargla (Algeria). Similarly Majdy et al. (2015) reported a value of 576 mg/l in the city of Rabat (Morocco). Our findings are higher to those found for the wastewater effluent in the region of Souk Ahras, North-East Algeria (Mamine et al., 2020).

This high increase in the COD is related to the increase in suspended matter which contains oxidizable matter.

The COD/BOD_5 ratio estimates the biodegradability of organic pollutants. The average value of COD/BOD_5 was found to be 1.84 (< 3) which means that the effluent has a good biodegradability and that the studied wastewater is majority of domestic origin (Bechac et al., 1984). The ratios obtained are similar to those reported in other previous studies (Mamine et al., 2020; Gnagne et al., 2015).Alternatively, Fresenius et al. (1990) reported that when BOD_5/COD ratio is ≥0.5, biological degradation begins immediately, whereas, when BOD_5/COD ratio is <0.5, there is a possibility that chemicals which have poor biodegradability delay the biological process. During the two years of the study. BOD_5/COD was 0.54 which indicates that the effluent has a high biodegradability.

The total suspended solids (TSS) were made up of inorganic materials, bacteria and algae. In terms of suspended solids, value was ranged between 120 mg/L and 250 mg/L for raw water. These values are superior to Algerian discharge standards (35 mg/L) (Fresenius et al., 1990). It is worth noting that several previous studies conducted in Algeria (Yahiaoui et al., 2020; Zegait & Boualem, 2018) reported similar results to that obtained in the present study.

Drip irrigation system

Fig. 3 shows the general layout and the main components of the proposed drip network calculated based on the peak flow of 32.4 m^3/h.

Drip irrigation system consists of the following components: lateral line. sub main line and main pipe carriers. The calculation of the drip network sizes gives different diameters: 11mm to 18 mm for the lateral line, 30mm to 50mm for sub main line and 63mm to 90mm for main line. According to the data of Tables 5, 6 and 7, the flow velocity was varied between 0.5m/s and 1.2 m/s.

Design hybrid wastewater treatment system

The design of the size of the constructed wetland is based on the volume of evacuated wastewater (778.5m^3/d) and takes into account the pollution parameter BOD_5 (325-365 mg/L). For the pretreatment purification, septic tanks were sized for two lines. The station will therefore have 5 septic tanks for a flow rate of 155.7 m^3 /d. A residence time of 12 hours was chosen for the

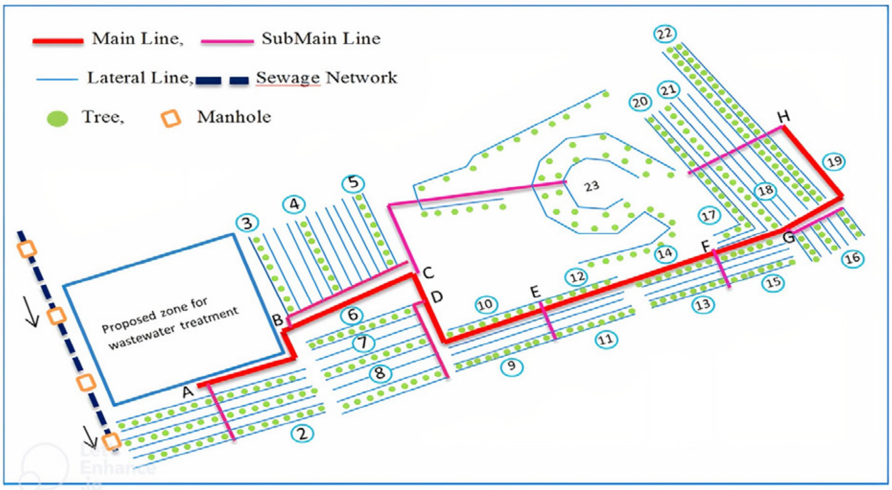

Fig 3. Layout of the proposed drip network for the garden of the new city of Ouled Djellal.

Table 5. Dimensions and hydraulic parameters of the lateral line.

Lateral line							
Parcel	Length (m)	Flow rate (m3/s)	Fc	Diameter (m)	Head loss (Hf)	Nominal diameter (m)	Velocity (m/s)
1	58	0.00013	0.391	0.01472	0.800	0.016	0.647
2	54	0.00013	0.391	0.01451	0.745	0.016	0.647
3	60	0.00013	0.391	0.01482	0.827	0.016	0.647
4	59	0.00013	0.391	0.01477	0.813	0.016	0.647
5	58	0.00011	0.397	0.01386	0.816	0.015	0.623
6	73	0.00013	0.391	0.01543	1.007	0.016	0.647
7	70	0.00015	0.384	0.01610	0.920	0.017	0.661
8	71	0.00013	0.391	0.01534	0.979	0.016	0.647
9	60	0.0001	0.402	0.01349	0.716	0.015	0.566
10	60	0.00015	0.384	0.01559	0.597	0.018	0.590
11	48	0.00008	0.415	0.01192	0.786	0.013	0.603
12	48	0.00013	0.391	0.01416	0.906	0.015	0.736
13	46	0.00008	0.415	0.01181	0.753	0.013	0.603
14	45	0.00012	0.394	0.01358	0.738	0.015	0.679
15	40	0.00007	0.425	0.01096	0.524	0.013	0.528
16	25	0.00005	0.457	0.00889	0.426	0.011	0.526
17	87	0.00019	0.377	0.01834	0.788	0.02	0.605
18	57	0.0001	0.402	0.01335	0.952	0.014	0.650
19	56	0.00012	0.394	0.01420	0.919	0.015	0.679
20	45	0.00011	0.397	0.01315	0.886	0.014	0.715
21	47	0.00008	0.415	0.01187	0.769	0.013	0.603
22	81	0.00015	0.384	0.01659	0.806	0.018	0.590
23	54	0.00004	0.486	0.00969	0.647	0.011	0.421
	137	0.0001	0.402	0.01599	0.889	0.017	0.441
	110	0.00005	0.457	0.01205	0.830	0.013	0.377
	160	0.00008	0.415	0.01526	0.953	0.016	0.398
	38	0.00004	0.486	0.00901	0.724	0.01	0.510
	56	0.00004	0.486	0.00976	0.671	0.011	0.421

Table 6. Dimensions and hydraulic parameters of the sub main line.

Sub main line						
Length (m)	Flow rate (m3/s)	Fc	Diameter (m)	Head loss (Hf)	Nominal diameter(m)	Velocity (m/s)
42	0.00156	0.394	0.0409	0.671	0.04	1.24
77	0.00159	0.391	0.0466	0.427	0.05	0.81
50	0.00132	0.402	0.0400	0.598	0.04	1.05
30	0.001	0.402	0.0324	0.215	0.04	0.80
28	0.00084	0.409	0.0300	0.599	0.03	1.19
34	0.0004	0.415	0.0236	0.454	0.025	0.82
60	0.00195	0.379	0.0476	0.470	0.05	0.99
154	0.00035	0.435	0.0309	0.327	0.035	0.36

Table 7. Dimensions and hydraulic parameters of the main line.

Main line						
N° ML	Length (m)	Flow rate (m^3/s)	Diameter (m)	Nominal diameter(m)	Head loss (H_f)	Velocity (m/s)
A B	78	0.00745	0.0889	0.09	1.10	1.17
B C	78	0.00586	0.0789	0.09	0.71	0.92
C D	20	0.00551	0.0765	0.08	0.29	1.10
D E	94	0.00419	0.0667	0.08	0.81	0.83
E F	105	0.00319	0.0582	0.063	1.75	1.02
F G	63	0.00235	0.0499	0.063	0.60	0.75
G H	81	0.00195	0.0455	0.063	0.54	0.63

pretreatment. A volume of 77.8m^3 was obtained using the following dimensions: depth h = 2 m; width l = 3.6 m and length L = 10.8 m.

For calculating dimensions of constructed wetland, the size of the horizontal surface filter and the vertical surface filter was calculated based in equation 1 (Reed et al., 1995) and 2 (Noorvee et al., 2005), respectively. The winter temperature of the measured raw wastewater was taken onsite and was found to be 10.17 °C. The design of filters was based on the criteria and recommendations of the previous studies (Reed et al., 1995). These recommendations be summarized as follows: the constants K_r and q_R (as shown in Table 3), the particle size of the proposed gravel is 35% of porosity, the depth of the horizontal surface flow is h = 0.6 m; and h = 0.9 m for vertical surface flow.

The proposed plant for system is the Phragmite Australis, which gives good performance in removing organic matter under arid conditions (Mandi et al., 1996; Bensmina et al., 2014). The total required surface of the constructed wetland is 12285 m^2.

According to the physico-chemical analysis of wastewater (Table 3), the major pollution parameter that should be eliminated is BOD_5 (365 mg/L). In this regards, three parameters were selected: the available surface, the residence time and the integration of the proposed system in the urban environment. Three configurations for the proposed system were proposed:

- The first configuration: VF-HF (Seidel, 1965b), made up of vertical flow surface with a surface area of 6490 m^2 followed by horizontal flow surface with a surface of 10150 m^2 with a

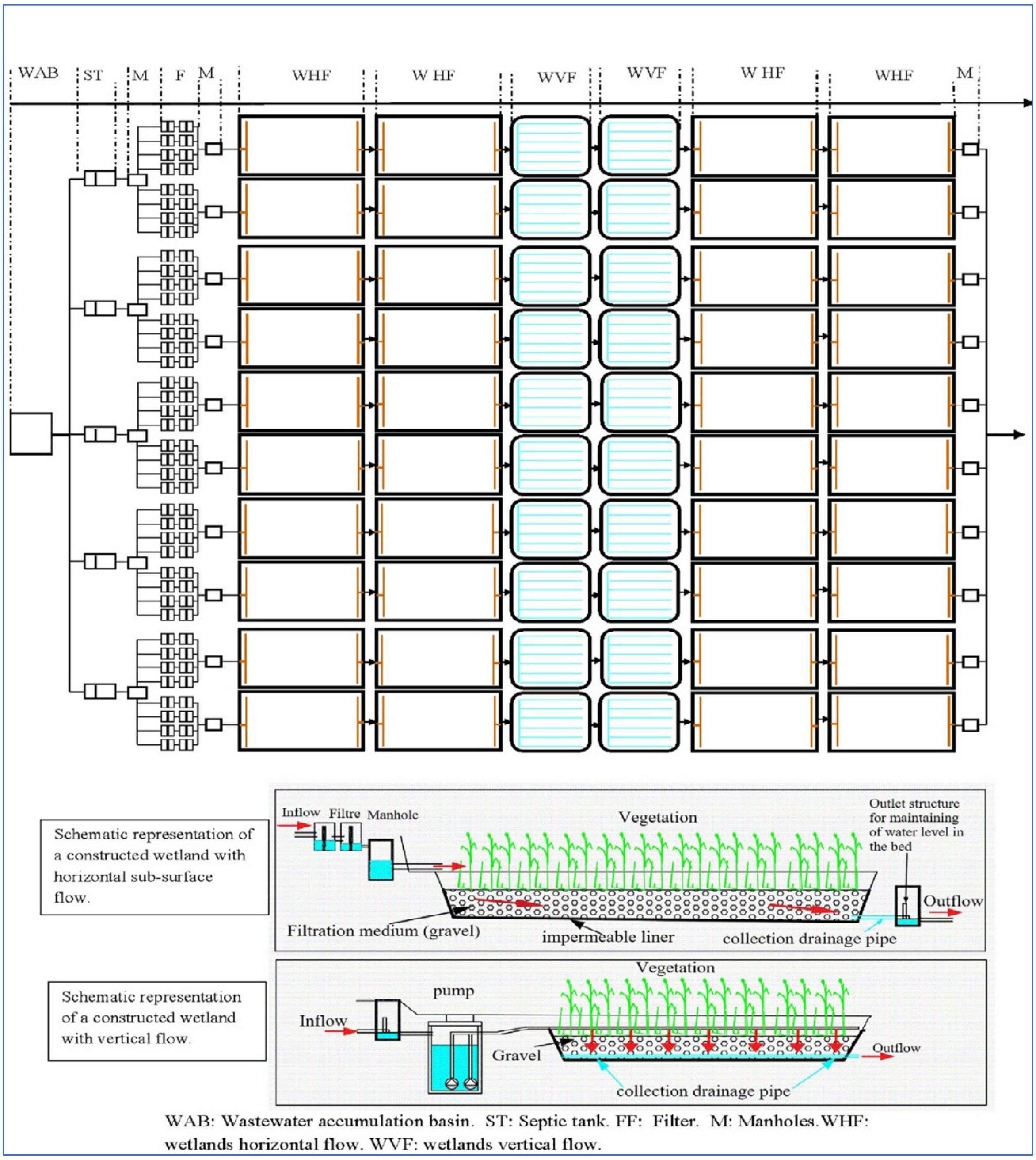

Fig 4. Design of a constructed wetlands system for wastewater treatment (HF-VF-HF).

total residence time of 5.4 days. Nevertheless, the total area being 16.637 m^2, which exceeds the area designated for the station (12.285 m^2).

- The second configuration: HF-VF (Johansen & Brix, 1996), composed of an horizontal flow surface with surface area of 5290 m^2 followed by a vertical flow surface with 3890 m^2 of surface. The residence time is 3 days, and the nitrified effluent from the VF bed must be recycled to the sedimentation tank (Brix et al., 2003). The configuration is valid considering the installation but it gives a surface less than the available surface.

- The third configuration (Fig 4) consists of a horizontal flow surface followed by a vertical surface flow, then another horizontal surface flow. The design and size of the constructed wetland is made up of 10 lines each supplied with two parallel lines and each line contained two horizontal flow surface posted in series with areas $HF_1 = HF_2 = 265\ m^2$. This surface can remove 58.9 % of BOD_5 at a concentration of 365 mg/L then two vertical filters in series ($VF_1 = VF_2 = 162\ m^2$). The VF can eliminate 66.66% of BOD_5 at a concentration of 150 mg/L. The latter followed by another horizontal system $HF_1 = HF_2 = 152\ m^2$ posted in series. This surface will remove 40% of BOD_5 at a concentration of 50 mg/L. The total area is estimated to be 11580 m^2 less than the available area with a residence time of 3.5 days largely sufficient for the wastewater treatment. Thus, the third configuration (HF-VF-HF) was adopted in order to avoid the realization of a recycling system for the case of the second configuration. The treated water is conveyed by a drip system previously sized (Fig.3).

CONCLUSION

The constructed wetlands (CWs) technology has a great potential for the treatment of wastewater. In this study, the integration of a small unity of CW in the urban environment was investigated and reuse of treated water for the irrigation of green space. The design of the treatment system was based on the characteristic of raw wastewater and the available surface area in the studied city. Results of the COD/BOD_5 ratio indicate that the wastewater is of domestic origin and is easily biodegradable. The proposed drip network for the landscape irrigation was calculated based on the peak flow of 32.4 m3 /h. The configuration adopted for the CW system is HF-VF-HF and occupies an area of 11.580 m^2. Findings of this work showed that the proposed design would be effective in reducing water pollution in the urban environment and providing the option of reuse water.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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