JEE Journal of Ecological Engineering

Journal of Ecological Engineering 2023, 24(11), 257–267
https://doi.org/10.12911/22998993/171751
ISSN 2299–8993, License CC-BY 4.0

Received: 2023.07.13
Accepted: 2023.08.31
Published: 2023.09.19

Evaluation of Evapotranspiration and Performance of Emerging Plants: Case of *Cyperus papyrus* and *Typha latifolia*

Loubna Benrahmane[1*], Latifa Mouhir[1], Mohamed Laaouan[2], Mustapha El Hafidi[2], Laila Saafadi[1]

[1] Laboratory of Process Engineering & Environment, Faculty of Sciences & Techniques, Hassan II University of Casablanca, BP 146, Mohammedia, 28806, Morocco

[2] International Institute of Water and Sanitation of the National Office of Electricity and Drinking Water – Water Branch, Avenue Belhassan El Ouazzani, Rabat Chellah, 10002, Morocco

* Corresponding author's e-mail: loubnabenrahmane89@gmail.com

ABSTRACT

The treatment of wastewater in small rural settlements requires special attention in the choice of the purification technique to be used, insofar as experience has shown that the technologies initially developed for the urban environment do not prove to be as effective for the rural environment. The current trend tends towards autonomous systems. Among these systems are Floating treatment wetlands. The objective of this study was to evaluate the evapotranspiration and the performances of two emerging plants; *Cyperus papyrus* and *Typha latifolia*. The experimental device was composed of three test tanks whose dimensions were: length = 1 m, width = 1 m and water height = 0.85 m – two tanks with emerging plants (*Cyperus papyrus* and *Typha latifolia*) and a control tank without vegetation. The monitoring of the evolution of plant evapotranspiration and the evaporation of the control tank for different periods and temperatures showed that the volumes of water lost were respectively for *Cyperus papyrus*, *Typha latifolia* and control tank: (1) 130 liters, 230 liters and 5 liters for two days at an average temperature of 26.3 °C; (2) 125 liters, 150 liters and 0 liters for two days at an average temperature of 26.7 °C; (3) 240 liters, 280 liters and 5 liters for three days at an average temperature of 27.3 °C; (4) 140 liters, 260 liters and 10 liters for two days at an average temperature of 26 °C; (5) 140 liters, 240 liters and 5 liters for two days at an average temperature of 27.3 °C; (6) 260 liters, 550 liters and 10 liters for four days at an average temperature of 28.6 °C. It turned out that the presence of plants as well as the temperature and the retention time in the tanks have a impact on the loss of water and more precisely those with emerging macrophytes. The present study has shown that the floating treatment wetlands planted with *Cyperus papyrus* and *Typha latifolia* can be used for wastewater treatment. Indeed, the removal efficiency in terms of COD, BOD_5 and SS were respectively: 76%, 75.3% and 95.90% for *Cyperus papyrus* and 70.45%, 66.5% and 93.70% for *Typha latifolia*.

Keywords: evapotranspiration, evaporation, floating treatment wetlands, *Cyperus papyrus*, *Typha latifolia*, removal efficiency.

INTRODUCTION

The treatment of wastewater from small agglomerations in particular the rural environment constitutes one of the greatest environmental problems (absence of sewerage network, lack of treatment plant) which contribute to the spread of water diseases and to the contamination of surface and groundwater caused by the direct discharge of these waters in the raw state into the natural environment [Latrach et al., 2018]. This treatment requires particular attention in the choice of the purification technique to be used, insofar as experience has shown that the technologies initially developed for the urban environment do not prove to be as effective for the rural environment [Fahd et al., 2007]. The current trend tends towards phyto-purification which is characterized by a low operating and maintenance cost among these systems: the floating treatment wetlands which represent a variant in the family of wetlands with surface flow. In these systems, the plants develop their aerial tissues above the water level (above the carpet), while the root system develops hydroponically through the water column (under the carpet), acquiring nutrients and other elements directly from it and stimulating the function of a bacterial biofilm [Tanner and Headly, 2011].

Evapotranspiration (ET) describes the transport of water from the surface to the atmosphere, i.e. the sum of the direct evaporation of water and transpiration by plants [Allen et al., 1998]. This is an important phenomenon in wetlands, because it is their main mechanism for water loss [Papaevangelou et al., 2012]. It is a combination between evaporation which is a physical process that results in the passage of water from a liquid state to a gaseous state (vapor) and transpiration is the loss of water in the atmosphere by evaporation from the aerial parts of a plant, such as the leaves.

Evaporation and transpiration occur simultaneously and depend on local weather conditions such as solar radiation, atmospheric pressure, relative humidity, air temperature and wind speed [Zotarelli et al., 2010]. In small-scale treatment wetlands, ET is mainly powered by solar radiation and air heat transfer and is often very seasonal [Kadlec and Wallace, 2009]. Excessive water loss due to ET can have an impact on the efficiency of pollutant removal, due to the reduction in the volume of waste water in the outflow and the concentration of pollutants in the system.

The aim of this study is to evaluate the evapotranspiration of two plants: *Cyperus papyrus* and *Typha latifolia* used in the treatment of wastewater by the floating treatment wetlands, and compare their results with a control tank (tank without planting), as well as the evaluation of the purification performance of these plants in terms of water purification.

MATERIALS AND METHODS

Study site

The experiment was conducted at the level of the test pilots of the International Institute of Water and Sanitation of the ONEE-Water Branch at the Bouregreg Complex in Rabat, which is located in the upstream of the Bouregreg valley and downstream of part the Sidi Mohamed Ben Abdallah, Northwest of Morocco.

Experimental setup

The plants studied are *Cyperus papyrus* (CP) and *Typha latifolia* (TL). The CP was taken up from a filter implanted in the same study site [El Hafidi, 2021], on the other hand the TL was taken in a marshy area on the bank of Wadi Bouregreg in Rabat (Figure 1).

Cyperus papyrus (CP), commonly called papyrus, is a member of the *Cyperaceae* family that has about 75 genera and more than 4,000 species. It once grew wild throughout the Nile Valley (Egypt, Ethiopia) and can still be found in the swamps and marshes of Central, East and Southern Africa [Monier et al. 2011; Chale 1987; van Dam et al. 2011; Boar et al. 1999].

Typha latifolia (TL) also known as cattail in American English [Revedin et al., 2010], broad-leaved cattail [Alex et al., 1980], cane, reed cane, bed grass, water mass, club, club with broad leaves, cattail, reed, marsh reed and broad-leaved typha. It is a plant of the *Typhaceae* family. It is the most common species of the genus Typha. The experimental setup is illustrated in Figure 2.

CP and TL plants were planted in the tank in mid-July at a density of 09 plants per square meter (m^2) for each plant type. The test tanks were supplied with wastewater. The wastewater was

Figure 1. Marshy area on the bank of the Bouregreg

pre-treated (bar screening and desander) and fed to the test tanks via a submersible pump.

Monitoring protocol for evapotranspiration (ET) and evaporation (E)

Evapotranspiration and evaporation were calculated by subtracting the volume of water lost after every 24 hours, using daily measurements of water volume (length · width · height of water) for the three test tanks during the hottest month of the study area.
The protocol was as follows:
- filling of the 3 tanks with pre-treated wastewater (the volume is set at 850 liters for each tank: this is the initial volume),
- measure the water level after 24 hours for each tank and record it on the monitoring sheet,
- the next day, measure the water level again for the three tanks, and so on.

The lost volume or the evapotranspiration (ET) was equal to: ET (or E) = initial volume – volume after every 24 hours.

The monitoring periods of the evapotranspiration and the evaporation of the three test tanks were spread out from August 08 to August 23, 2022.

Sampling and analysis

To evaluate the phyto-purification of the two emerging plants that were the object of study in wastewater treatment, a measurement campaign was carried out by carrying out six tests by measuring the three basic pollution control parameters (COD – BOD_5 and SS) and comparing them with those of the control tank without vegetation. The procedure followed was as follows:
- the hydraulic retention time (HRT) is 4 days,
- samples are taken at the half-drain level, then the 3 tanks are topped up with fresh wastewater.

The protocol of physicochemical analysis used was based on the following methods:
- Chemical Oxygen Demand (COD): this parameter was determined by applying the disposable tube method with integrated reagents: $K_2Cr_2O_7$, H_2SO_4, Ag_2SO_4 and $HgSO_4$. It consisted in oxidizing most of the organic compound and some oxidizable mineral salts.
- Biological Oxygen Demand for 5 days (BOD_5): this parameter was measured after 5 days at a temperature equal to 20 °C and in the dark in order to avoid photosynthesis. It was determined by the dilution method where the sample to be measured was diluted.
- Suspended solids (SS): this parameter was determined by filtration through a filter membrane having a porosity of 1.2 µm [AFNOR, 1994] already rinsed and dried at 105 °C.

RESULTS AND DISCUSSIONS

Evapotranspiration and evaporation

The wastewater feeding the test tanks came from the frame city located the ONEE in Rabat (Morocco). The Table 1 and Figures 3–8 present the volumes lost at the level of each tank (CP, TL and control tanks) during the monitoring periods by presenting the values of the temperature [www.Accuweather.com, 2022]:

Table 2 presents the temperatures recorded during the monitoring periods of evapotranspiration and evaporation. The volume of waste water in the three test tanks was studied in order to examine the impact of plants on the phenomenon of evapotranspiration and compare it with that of the control. The Figures 3–8 show the loss of the volumes of waste water in the tanks of *Cyperus papyrus* and *Typha latifolia*, on the other hand the volume of water in the control tank remained almost stable.

For the first follow up period from 08 to 10 August 2022, with an initial volume of 850 liters in each of the three tanks, it was found after 24 hours (1st day) a loss of 70 liters for CP, 140 liters for TL and 5 liters for the control. The next day (2nd day) it was also noticed a loss of 60 liters for CP, 90 liters for TL and no loss was recorded for the control. That was a total of 130 liters for CP, 230 liters for TL and 5 liters for the control.

For the second follow up period from 10 to 12 August 2022, with an initial volume of 850 liters in each of the three tanks, it was noticed after 24 hours (1st day) a loss of 65 liters for CP and 95 liters for TL. The next day (2nd day) it was also found a loss of 60 liters for CP and 55 liters for TL. That was a total of 125 liters for CP and 150 liters for TL. No loss was recorded for the control during this period.

For the third follow up period from 12 to 15 August 2022, with an initial volume of 850 liters in each of the three tanks, it was found after

Figure 2. The experimental setup : (a) Tank of CP; (b) Tank of TL; (c) control tank

Table 1. Volume of water lost in the three test tanks as a function of temperature

Period	Dates	Volume of water lost in liters (CP tank)	Volume of water lost in liters (TL tank)	Volume of water lost in liters (control tank)	Temperature average (°C)	Remarque
August 08 to 10, 2022	08 au 09/08/22	70	140	5	26,3	Filling again on 10/08/22
	09 au 10/08/22	60	90	0		
	Total	130	230	5		
August 10 to 12, 2022	10 au 11/08/22	65	95	0	26,7	Filling again on 12/08/22
	11 au 12/08/22	60	55	0		
	Total	125	150	0		
August 12 to 15, 2022	12 au 13/08/22	80	70	0	27,3	Filling again on 15/08/22
	13 au 14/08/22	80	170	5		
	14 au 15/08/22	80	40	0		
	Total	240	280	5		
August 15 to 17, 2022	15 au 16/08/22	100	150	5	26	Filling again on 17/08/22
	16 au 17/08/22	40	110	5		
	Total	140	260	10		
August 17 to 19, 2022	17 au 18/08/22	100	150	0	27,3	Filling again on 19/08/22
	18 au 19/08/22	40	90	5		
	Total	140	240	5		
August 19 to 23, 2022	19 au 20/08/22	50	130	0	28,6	Filling again on 23/08/22
	20 au 21/08/22	50	140	5		
	21 au 22/08/22	50	130	0		
	22 au 23/08/22	110	150	5		
	Total	260	550	10		

24 hours (1st day) a loss of 80 liters for CP, 70 liters for TL and 0 liter for the control. The next day (2nd day) it was also noticed a loss of 80 liters for CP, 170 liters for TL and 5 liters for the control. The monitoring of the volume of the water during the 3rd day showed a loss of 80 liters for CP, 40 liters for TL and 0 liter for the control. That wa s a total of 240 liters for CP, 280 liters for TL and 5 liters for the control.

For the fourth follow up period from 15 to 17 August 2022, with an initial volume of 850 liters in each of the three tanks, it was found after 24 hours (1st day) a loss of 100 liters for CP, 150 liters for TL and 5 liters for the control. The next day (2nd day) it was also noticed a loss of 40 liters for CP, 110 liters for TL and 5 liters for the control. That was a total of 140 liters for CP, 260 liters for TL and 10 liters for the control.

For the fifth follow up period from 17 to 19 August 2022, with an initial volume of 850 liters in each of the three tanks, it was noticed after 24 hours (1st day) a loss of 100 liters for CP, 150 liters for TL and 0 liter for the control. The next day (2nd day) it was also found a loss of 40 liters for CP, 90 liters for TL and 5 liters for the control. That was a total of 140 liters for CP, 240 liters for TL and 5 liters for the control.

For the sixth follow up period from 19 to 23 August 2022, with an initial volume of 850 liters in each of the three tanks, it was found after 24 hours (1st day) a loss of 50 liters for CP, 130 liters for TL and 0 liters for the control. The next day (2nd day) it was also noticed a loss of 50 liters for CP, 140 liters for TL and 5 liters for the control. The monitoring of the volume of the water during the 3rd day showed a loss of 50 liters for CP, 130 liters for TL and 0 liters for the control. For the 4th day, a loss of 110 liters, 150 liters and 5 liters was recorded for CP, TL and control after 24 hours (4th day). That was a total of 260 liters for CP, 550 liters for TL and 10 liters for the control.

The global analysis of these results by comparing them with those of the control tank, it was found that the loss of water in the tanks where the emerging plants *Cyperus papyrus* and *Typha latifolia* were installed was due to the transpiration of the plants and to

Table 2. The monitoring periods according to the temperature

Period	Dates	Temperature (°C)	Temperature average (°C)
August 08 to 10, 2022	08/08/2022	27	26,3
	09/08/2022	26	
	10/08/2022	26	
August 10 to 12, 2022	10/08/2022	26	26,7
	11/08/2022	26	
	12/08/2022	28	
August 12 to 15, 2022	12/08/2022	28	27,3
	13/08/2022	28	
	14/08/2022	27	
	15/08/2022	26	
August 15 to 17, 2022	15/08/2022	26	26
	16/08/2022	26	
	17/08/2022	26	
August 17 to 19, 2022	17/08/2022	26	27,3
	18/08/2022	27	
	19/08/2022	29	
August 19 to 23, 2022	19/08/2022	29	28,6
	20/08/2022	31	
	21/08/2022	29	
	22/08/2022	28	
	23/08/2022	26	

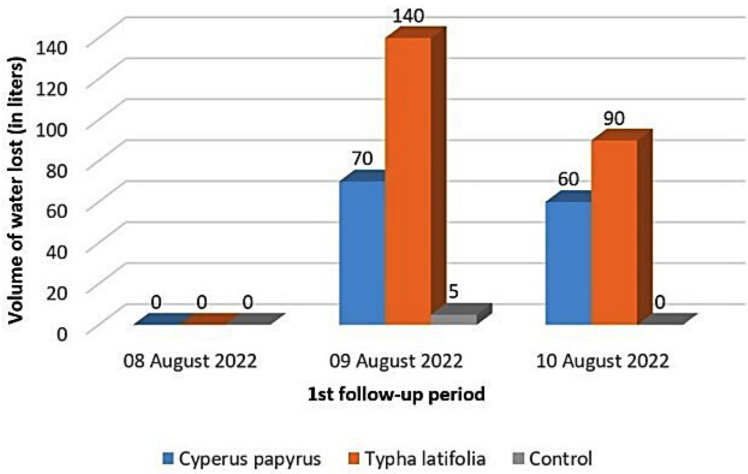

Figure 3. Evolution of the evapotranspiration of the different plants from August 08 to 10, 2022

the variation of the temperature. The latter is a main meteorological parameter that affects the evapotranspiration of plants [Choudhary, 2018]. In other words, the presence of vegetation is the most important factor in water losses, the ET being considerably higher than in systems without vegetation [Nivala et al., 2022]. It is also noticed that the evapotranspiration at the level of *Typha latifolia* was higher than at the level of *Cyperus papyrus*.

Analysis of raw wastewater

The samples were taken at the intlet and outlet of each tank. The Table 3 shows the results of the physico-chemical parameters measured at the tank inlets.

The analysis of the raw watewater show that COD varied from 217 mg of O_2/l to 414 mg of O_2/l with an average of 327.7 mg of O_2/l. The BOD_5 oscillated from 103 mg of O_2/l and

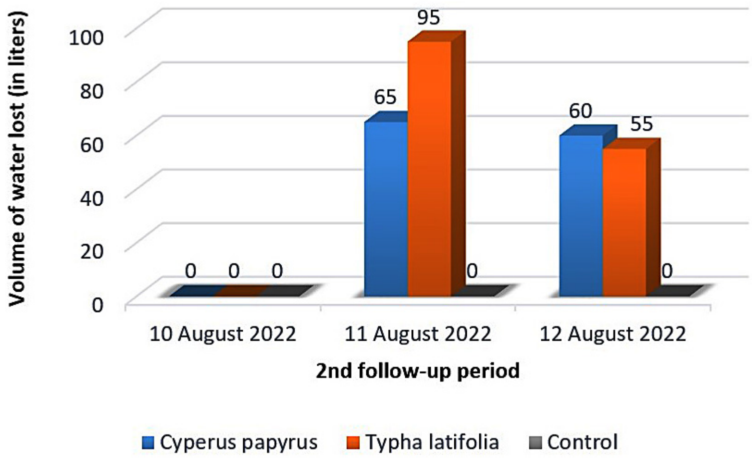

Figure 4. Evolution of the evapotranspiration of the different plants from August 10 to 12, 2022

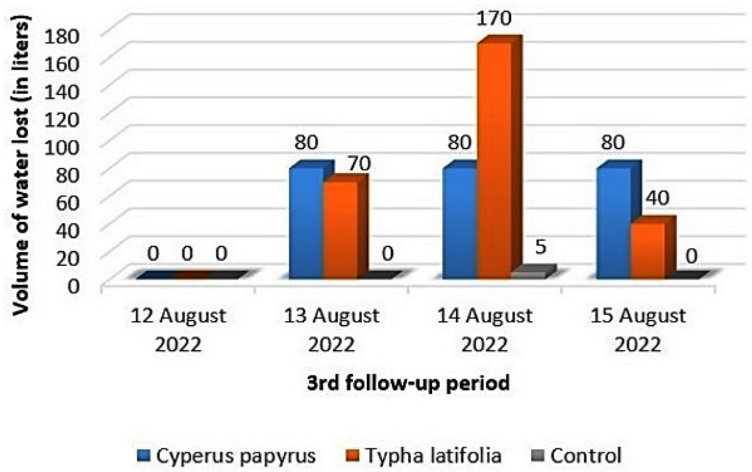

Figure 5. Evolution of the evapotranspiration of the different plants from August 12 to 15, 2022

207 mg of O_2/l with an average of 149.8 mg of O_2/l and the SS varied between 192.5 mg/l and 361 mg/l with an average of 269.8 mg/l.

Analysis of phyto-purification of wastewater by *Cyperus papyrus* and *Typha latifolia*

The two plants (CP and TL) were studied for a hydraulic retention time of 4 days. The Figures 9, 10 and 11 illustrate the results of analyses of the physico-chemical parameters studied.

The COD content at the inlet oscillated between 217 and 414 mg O_2/l. Then, this concentration decreased after phyto-purification by *Cyperus papyrus* to a value that varied from 67 to 92 mg O_2/l with an average of 75.7 mg O_2/l and for *Typha latifolia*, it oscillated between 80 and 109 mg O_2/l with an average of 93.50 mg O_2/l. On the other hand, the COD at the outlet of the control tank (without vegetation) oscillated between 123 and 241 mg O_2/L with an average of 162.2 mg O_2/l (Figure 9).

The BOD_5 concentration at the inlet varied from 103 to 207 mg O_2/l. This content was reduced by *Cyperus papyrus* to a value that oscillated between 33 and 37.5 mg O_2/l with an average of 35 mg O_2/l and for *Typha latifolia*, it varied from 42 to 53 mg O_2/l with an average of 47.3 mg O_2/l. However, the BOD_5 content at the outlet of the control varied from 77 to 120.5 with an average of 90.9 mg O_2/l (Figure 10).

The SS content before treatment varied from 192.5 to 361 mg/l. After treatment with *Cyperus papyrus*, this concentration was reduced to between 6 and 15 mg/l, with an average of 10.5 mg/l. For the other plant (*Typha latifolia*), this content was reduced to a value varied between 9.5 and 23 mg/l, with an average of 16.6 mg/l. On the other hand, the SS concentration at the control outlet varied from 17 to 37.5 mg/l, with an average of 26.8 mg/l (Figure 11).

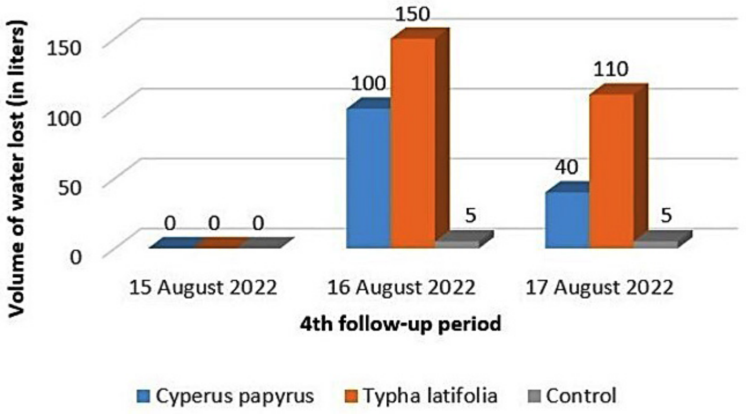

Figure 6. Evolution of the evapotranspiration of the different plants from August 15 to 17, 2022

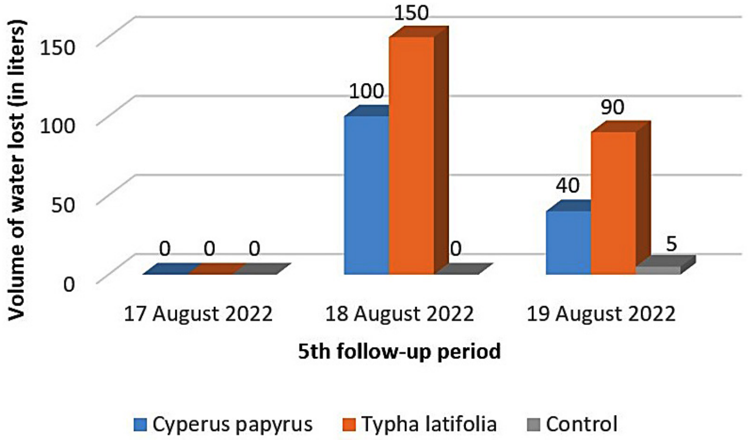

Figure 7. Evolution of the evapotranspiration of the different plants from August 17 to 19, 2022

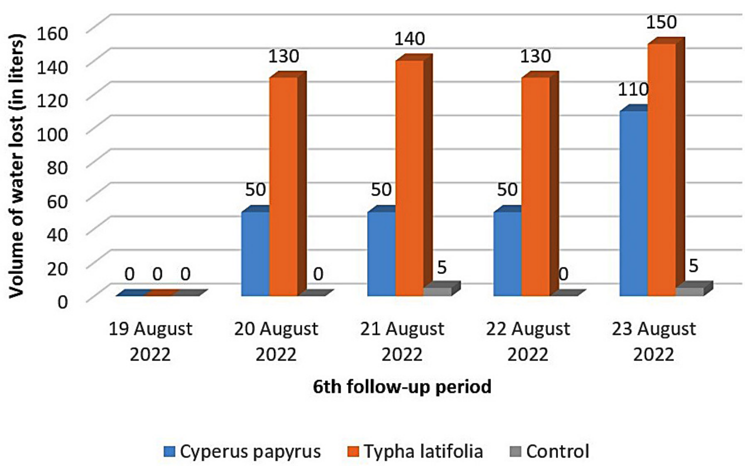

Figure 8. Evolution of the evapotranspiration of the different plants from August 19 to 23, 2022

The summary of the removal efficiency of the pollution parameters (COD, BOD_5 and SS) is illustrated in the Table 4.

Macrophytes directly influence the performance of the treatment by the absorption of nutrients, the sedimentation and trapping of solids, the degradation of organic matter and the provision of aesthetic coverage [Ijaz et al., 2015]. According to Table 4, it can be seen that *Cyperus papyrus* and *Typha latifolia* play a very important role in the purification of wastewater, which translates into very high

Table 3. Raw wastewater quality parameters

Tests	COD (mg O_2/l)	BOD_5 (mg O_2/l)	SS (mg O_2/l)
Test 1	414	207	361
Test 2	384	183	280
Test 3	284	142	217
Test 4	217	103	192,5
Test 5	382	134	340
Test 6	285	129,5	228
Average value	327,7	149,8	269,8

Table 4. Removal efficiency of the pollution parameters

Test variants	COD (%)	BOD_5 (%)	SS (%)
Cyperus papyrus	76	75.3	95.90
Typha latifolia	70.45	66.5	93.70
Control	49.29	37.2	89.73

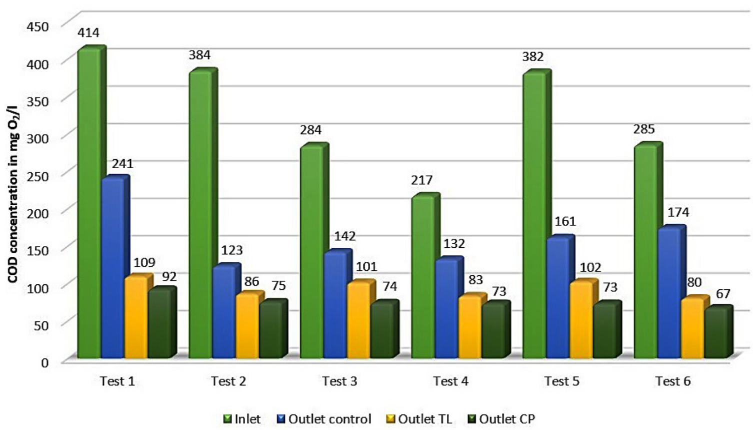

Figure 9. COD variation before and after treatment

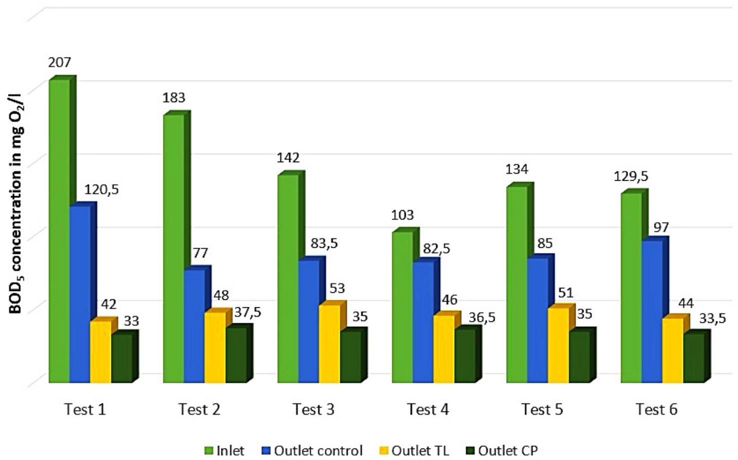

Figure 10. BOD_5 variation before and after treatmen

removal efficiency which exceed 76% COD, 75% BOD_5 and 95% SS. On the other hand, the efficiency of the control is moderately efficient for COD and BOD_5.

CONCLUSIONS

The present study relating to the monitoring of the evolution of evapotranspiration and

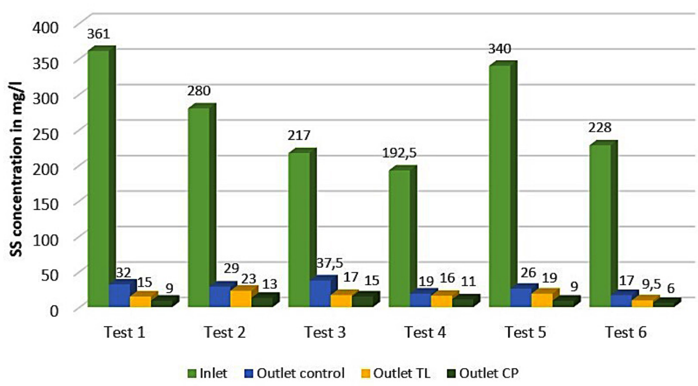

Figure 11. SS variation before and after treatment

evaporation has shown that the volume of water lost for *Cyperus papyrus*, *Typha latifolia* and the control tank is respectively as follows:

- 130 liters, 230 liters and 5 liters for two days at an average temperature of 26.3 °C,
- 125 liters, 150 liters and 0 liters for two days at an average temperature of 26.7 °C,
- 240 liters, 280 liters and 5 liters for three days at an average temperature of 27.3 °C,
- 140 liters, 260 liters and 10 liters for two days at an average temperature of 26 °C,
- 140 liters, 240 liters and 5 liters for two days at an average temperature of 27.3 °C,
- 260 liters, 550 liters and 10 liters for four days at an average temperature of 28.6 °C.

It is concluded that the presence of plants as well as the temperature and the retention time in the tanks has a very significant impact on the loss of water in the tanks and more precisely the emerging macrophyte tanks (*Cyperus papyrus* and *Typha latifolia*) which will subsequently impact the elimination of pollutants. In other words, the presence of vegetation is the most important factor in water losses, with the ET being considerably higher than in systems without vegetation.

The purifying performances of the emerging plants *Cyperus papyrus* and *Typha latifolia* show the very important role in the treatment of wastewater. These performances are reflected in the removal efficiency in terms of COD, BOD_5 and SS which are equal to:

- *Cyperus papyrus*: COD = 76%, BOD_5 = 75.3% and SS = 95.90%,
- *Typha latifolia*: COD = 70.45%, BOD_5 = 66.5% and SS = 93.70%.

Acknowledgements

The authors of this article thank very much the operator working at the level of the International Institute of Water and Sanitation of the National Office of Electricity and Drinking Water for any effort made to succeed in this work.

REFERENCES

1. AFNOR, 1994. Water quality, Environment. Collection of French standards (in French). Paris.
2. Alex J.F., Mulligan G.A. and Cayouette R. 1980. Common and botanical names of weeds in Canada. Canadian Government Publishing Centre, Ottawa.
3. Allen R.G., Pereira L.S., Raes D. and Smith M. 1998. Crop Evapotranspiration. FAO Irrigation and drainage paper No. 56. Food and Agriculture Organization of the United Nations, Rome.
4. Boar R.R., Harper D.M. and Adams C.S. 1999. Biomass allocation in Cyperus papyrus in a tropical wetland, Lake Naivasha, Kenya. Biotropica, 31(3), 411–421.
5. Chale F. 1987. Plant biomass and nutrient levels of a tropical macrophyte (Cyperus papyrus L.) receiving domestic wastewater. Aquatic Ecology, 21(2), 167–170.
6. Choudhary D. 2018. Methods of Evapotranspiration. Ph.D. Thesis, Chaudhary Charan Singh Haryana Agricultural University, Hisar, India.
7. Monier A.E., El-Fiky A.M., Soliman A. and Khattab A. 2011. Environmental relationships of aquatic vegetation in the fresh water ecosystem of the Nile Delta, Egypt. African Journal of Ecology, 49(1), 103–118.
8. El Hafidi M. 2021. Phyto-purification of domestic wastewater on a vertical filter planted with Cyperus papyrus: optimization of design parameters and cost analysis (In French). Ph.D. Thesis, Mohammedia University, Rabat, Morocco.

9. Fahd K., Martín I. and Salas J.J. 2007. The carrión de los céspedes experimental plant and the technological transfer centre: urban wastewater treatment experimental platforms for the small rural communities in the Mediterranean area. Desalination, 215, 12–21.
10. Ijaz A., Shabir G., Khan Q.M. and Afzal M. 2015. Enhanced remediation of sewage effluent by endophyte-assisted floating treatment wetlands. Ecological Engineering 84, 58–66.
11. Nivala J., Scott W., Van Afferden M. and Müller R. A. 2022. Evapotranspiration dynamics in aerated and non-aerated subsurface flow treatment wetlands. Science of the Total Environment, 843, 156605.
12. Kadlec R.H. and Scott D.W. 2009. Treatment Wetlands. Second edition. CRC Press, Boca Raton, Florida.
13. Latrach L., Belloulid M.O., El Moussaoui T., Bougarrani S., Elfanssi S. and Elassri O. 2018. Rural sanitation in morocco: situation, realizations and perspectives. Environmental and Water Sciences, Public Health & Territorial Intelligence, 2(3), 63–72.
14. Papaevangelou V.A., Gikas G. D. and Tsihrintzis V.A. 2012. Evaluation of evapotranspiration in small on-site HSF constructed wetlands. Journal of Environmental Science and Health, Part A, 47(5), 766–785.
15. Revedin A., Aranguren B., Becattini R., Longo L., Marconi E., Lippi M., Skakun N., Sinitsyn A., Spiridonova E. and Svoboda J. 2010. Thirty thousand-year-old evidence of plant food processing. Proceedings of the National Academy of Sciences of the United States of America, 107 (44), 18815–18819.
16. Tanner C.C. and Headley T.R. 2011.Components of floating emergent macrophyte treatment wetlands influencing removal of stormwater pollutants. Ecological Engineering, 37, 474–486.
17. Van Dam A., Kipkemboi J., Zaal F. and Okeyo-Owuor J.B. 2011. The ecology of livelihoods in East African papyrus wetlands (ECOLIVE). Reviews in Environmental Science and Biotechnology, 10(4), 291–300.
18. www.Accuweather.com, weather data of the city of Rabat 2022 (in French).
19. Zotarelli L., Dukes M.D., Romero C.C., Micgliaccio K.W. and Morgan K.T. 2010. Step by Step Calculation of the Penman-Monteith Evapotranspiration (FAO-56 Method). Agricultural and Biological Engineering Department, UF/IFAS Extension, Gainesville, Florida, USA.