



## Comparison between Vertical-Horizontal and Horizontal-Vertical hybrid constructed wetlands.

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### Abstract

Water pollution cause serious health risk to public. Treating wastewater in allow cost efficient way is necessary for the region. This project was designated to describe the usefulness of macrophytes *Typha angustifolia* L and *Phragmites australis*, since this could be an index for its utility as a biological purifier for advanced treatment of wastewater. For this purpose a specific model treatment project was hybrid constructed wetland. Constructed wetlands have become a good alternative to urban wastewater treatments. To achieve higher treatment performances, the HCW has various types. The project consists of several purification treatment units; Storage tanks, pre-sedimentation and two hybrid constructed wetlands. They are designed as (Vertical-Horizontal and Horizontal-Vertical) HCW, along with sand filtration implemented with two local macrophytes (*Typha angustifolia* and *Phragmites australis*). Experimental hybrid constructed wetlands contain macrophytes, they have grown for 50 days (the period needed for stabilization and adaptation), and taken untreated and treated wastewater samples twice a month periods from June 15, 2013 until September 15, 2013. Water samples were analyzed to determine the some heavy metals in inlet and outlet HCW. Results showed that the decreases in Iron, Copper, Cadmium and Lead contents in the outlet wastewater treatment in (Vertical-Horizontal) HCW higher decreases than (Horizontal-Vertical) HCW. These results showed the design (Vertical-Horizontal) HCW better than the design (Horizontal-Vertical) HCW to wastewater treatment.

### Introduction

Constructed wetlands (CWs) for the purpose of wastewater treatment, also called treatment wetlands, can be defined as engineered or manmade systems that utilise wetland plants, sediments and their associated microbial assemblages to treat an effluent or other water sources[1].Water is essential for maintaining, an adequate food supply and productive environment for the human population, animals, plants and microbes worldwide[2].Population and economics grow, accompanied by increased water use, will not only severely reduce water availability per person but also create stress biodiversity in entire global ecosystem [3] cited from [4].

The use of constructed wetlands to reduce the effect of the wastewater for irrigation crops and water purification is becoming more and more accepted and effective in many parts of the world [5 and 6]. In general, useful economic constructed wetlands require a little operation and maintenance when compared with technical treatment systems. Constructed wetlands are complex ecosystems that include physical, chemical and biological processes.

However, farmers around Sulaimani city are using untreated wastewater for irrigation undoubtedly a city with more than one million population faces a risk of diseases due to their consumption of uncooked foods irrigated by untreated wastewater. In the view of the fact that sewage treatment plants do not exist in Sulaimani city and the necessity of wastewater reclamation at least for the purposes of irrigation becomes an urgent need. Assess the applicability and performance of two stages hybrid system subsurface constructed wetlands (VSSF+HSSF) and (HSSF+VSSF) which were planted for wastewater purification at least for irrigation purposes. The main objective of the present study is to: To compare the efficiency for the possible wastewater purification in the different stage hybrid constructed wetlands (HSSF+VSSF and VSSF+HSSF) System, by using two local types of macrophyte namely (*T. angustifolia* and *Ph. australis*) for treatment wastewater for irrigation purposes were planted.

### **Description of the Studied Area:**

Kurdistan region mainly extends across the Zagros Mountain up to the Taurus Mountains in Turkey. The region lies between latitudes 34 ° 42 ' N and 37 ° 22 ' N and between longitudes 42 ° 25 ' and 46 ° 15 ' East. It has an elevation of 1400 meters above mean sea level (m.a.s.l.), and the highest point is the peak of Hasarost mountain in Erbil governorate, measuring 3607(m.a.s.l).

Sulaimani is one of the large cities of Kurdistan region of Iraq. Sulaimani city with a population density (1000000) civil (water demand = 220,000m<sup>3</sup>/day. It is surrounded by the mountains: Azmir, Goizha and Qaiwan. It ranges in the north east (with the highest peak of 1709 m above sea level), Baranan and Glazarda Mountains in the south (with the highest peak of 1373 m above the sea level) and the Tasluja Hills in the west (with the highest peak of 1118 m above sea the level ), [9]. Sulaimani is a governorate in Iraqi Kurdistan region which is located far north east of Iraq and southeast of the Iraqi Kurdistan Region. The international border with Iran represent the eastern boundary of the governorate where, it is bound north and northwest by Erbil governorate, west by Kirkuk governorate and Salahaddin governorate, and southwest and south by Diyala governorate. Sulaimani governorate occupies more than (1200 Km<sup>2</sup>) in Kurdistan of Iraq and lie between 43° 42 ' N and 36 ° 35 N and between longitudes 44 ° 55 and 46 ° 15 East .

### **Materials and methods:**

#### **A. Wastewater Sample Collection**

Water samples were collected from the influent storage tank, sedimentation unit and the hybrid CW outlet pipes for analysis. The untreated wastewater, after passing through the sedimentation storage tanks, was treated by hybrid constructed wetlands having macrophyte plants in the different stages of

treatment were collected. Wastewater outlet samples in the hybrid constructed wetland at different stages of treatment were taken after stabilization period (50 days), according to regular schedule at biweekly interval periods. The samples were analyzed for some heavy metals such as (Fe, Cu, Cd and Pb) during the studied period (June 15, 2013 to September 01, 2013). For the hybrid constructed wetland experiments, Samples were collected using clean large pre washed polyethylene containers. After collection of wastewater samples were brought back to laboratory kept in cool and dark condition as described by [7], for analysis purposes.

### **B. Trace Heavy Metals ( $\text{mg L}^{-1}$ )**

Using both inductively coupled plasma-optical emission spectroscopy ICP-OES were determined some heavy metals. All standard reference solutions were from the National Institute of Standards and Technology (NIST), USA. Some heavy metals, such as (Fe, Cu, Cd and Pb) were determined in untreated wastewater and treated wastewater.

### **C. Statistical analysis**

The obtained data from the present work were analyzed statistically following a software program that is known as a statistical package for social sciences and Microsoft Excel professional Edition 2007/ Data Analysis. However, analysis of variance (ANOVA) and complete randomized design (CRD) factorial were chosen as the experimental design for analysis purposes [8].

## **Design of the construction methods**

### **Storage tank and sedimentation unit for wastewater**

Two galvanized storage tanks were used for storage of wastewater; transported directly from the raw wastewater canal close to Kostay Cham/Bakrajo to the galvanized storage tanks, with cylinder shape with the capacity of 6160 L (plate 1). The sedimentation units consist of the polyethylene plastic tank having rectangular unit with specific dimension (110cm height, 100cm length and 95cm width) with 1045L capacity (plate 2). The storage tanks were covered by bag to prevent direct sunlight and high temperature. When the sedimentation unit was received the wastewater from the storage tank by the polyethylene pipe 42mm diameter after passing through the sieving unit, the sedimentation unit provided by a pipeline 42mm below the 30 cm of the top sedimentation unit because the clear zone started below 30 cm of the top. The pipeline supplied the wastewater to other distribution.





**Plate (1): Storage tanks A and B**

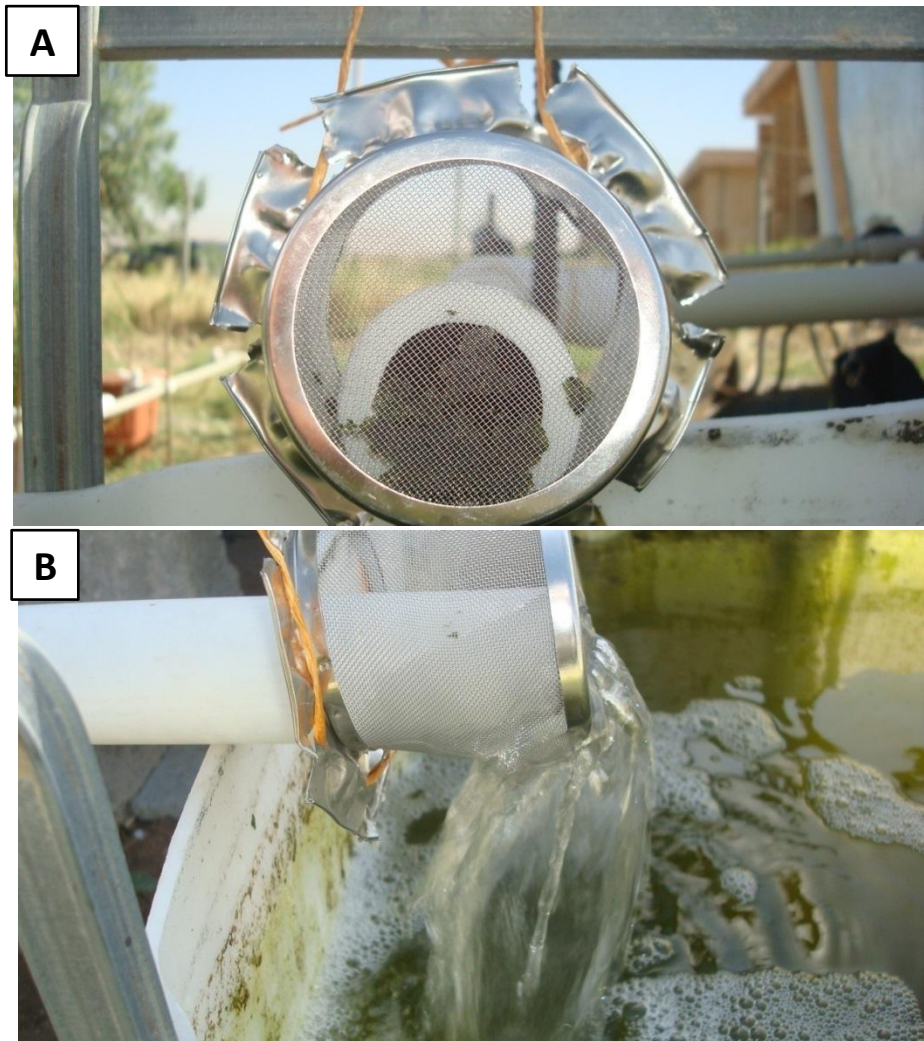


**Plate (2): Sedimentation unit**

**Inlet sieving unit for sedimentation unit**

One steel net (10mm) pore size carrying the effluent from the storage tanks to sedimentation tank which was used in as a sieve not to let the large particles to pass through the distribution

unit every day displaced the steel net not to let the clogging the pipes. This unit considered as a physical treatment stage, as shown in plate (3).



**Plate (3): Inlet sieving unit for sedimentation unit A and B.**

### **Distribution Systems**

A polyethylene pipeline was used to receive the effluent from the sedimentation unit from one side and discharge wastewater to the constructed wetland units from the other side. The main pipeline (42mm diameter) was receiving discharged wastewater to 3 sub –main pipeline (38mm diameter) which provided with valves to control the equal wastewater flow. The valves were connecting to a rubbery tube for draining wastewater to each hybrid constructed wetland (Plate 4). Wastewater treatment was collected by polyethylene pipeline (64mm diameter) at the outlet of each hybrid constructed wetland to prevent the flooding, also for easily movement throughout the project unit.



**Plate (4): Distribution Systems A and B**

**Plate (A): Started the distribution**

**Plate (B): Completed the distribution**

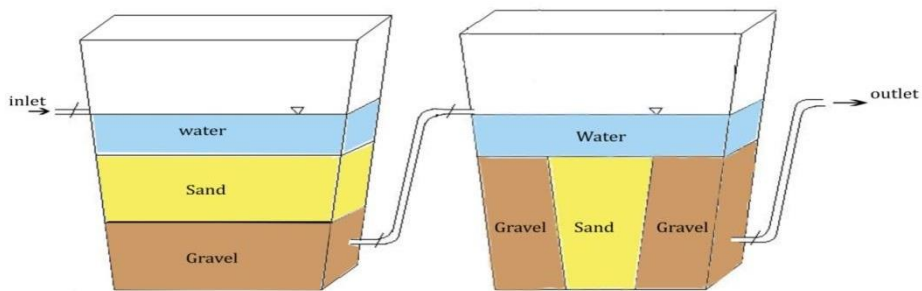
### **Hybrid constructed wetland system**

In this study, two types of hybrid constructed wetlands (HSSF-VSSF and VSSF-HSSF) were used (plate 5 and Scheme 1). The HCW consists of the plastic pot with specific dimensions (50cm height, 40cm length and 40cm width) with 80L capacity for one pot (plate 6). The influent (untreated wastewater) was entered to each the hybrid constructed wetlands from the top (14 cm below the top hybrid constructed wetland) with connected to the valve on the sub - main pipeline by tightening and loosening the rubbery tube. The effluent was drained from the bottom after percolating through the media. HSSF constructed wetlands consists of the 10 cm gravel media from two sides (before and after wetland) from the top to bottom (26cm height), the middle wetland

contain the 20 cm width sand media from top to bottom (26cm height) with 10 cm wastewater top of the media as shown in (plate 7 and Scheme 2). VSSF constructed wetland divided into three layers (13cm a gravel bottom layer, 13cm sand middle layer and 10cm wastewater top layer) as shown in (plate 8 and Scheme 3). Inside HCW, there were filtration media and Macrophyte.



**Plate (5): Hybrid constructed wetland**



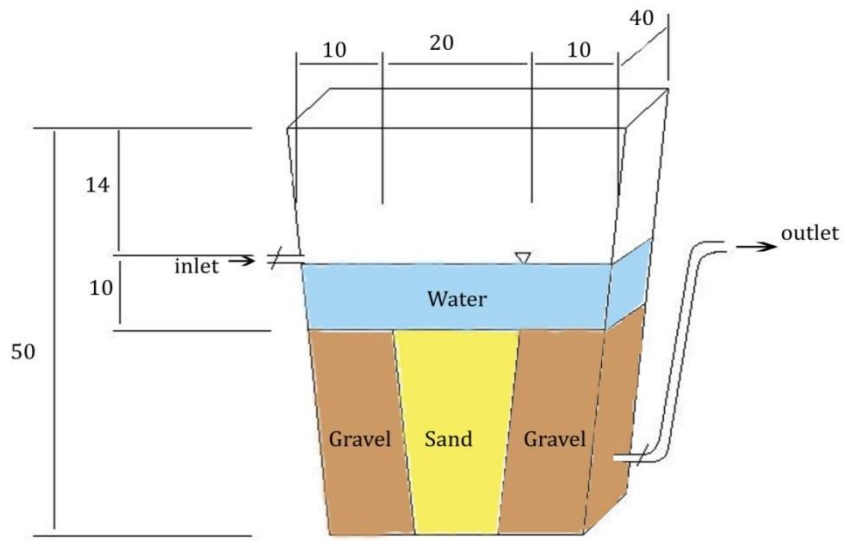
**Scheme (1): Schematic diagram of Hybrid constructed wetland**



**Plate (6): Design of the plastic Pot**



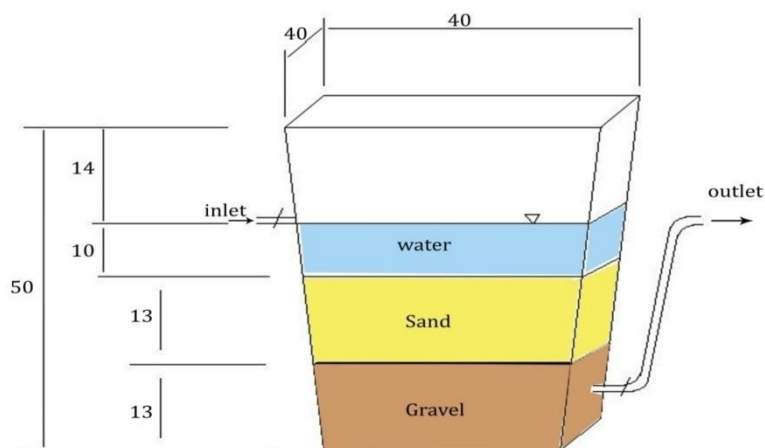
**Plate (7): Constructed wetland horizontal subsurface flow**



**Scheme (2): Schematic diagram of constructed horizontal subsurface flow**



**Plate (8): Constructed wetland vertical subsurface flow**



**Scheme (3): Schematic diagram of Constructed wetland vertical subsurface flow**

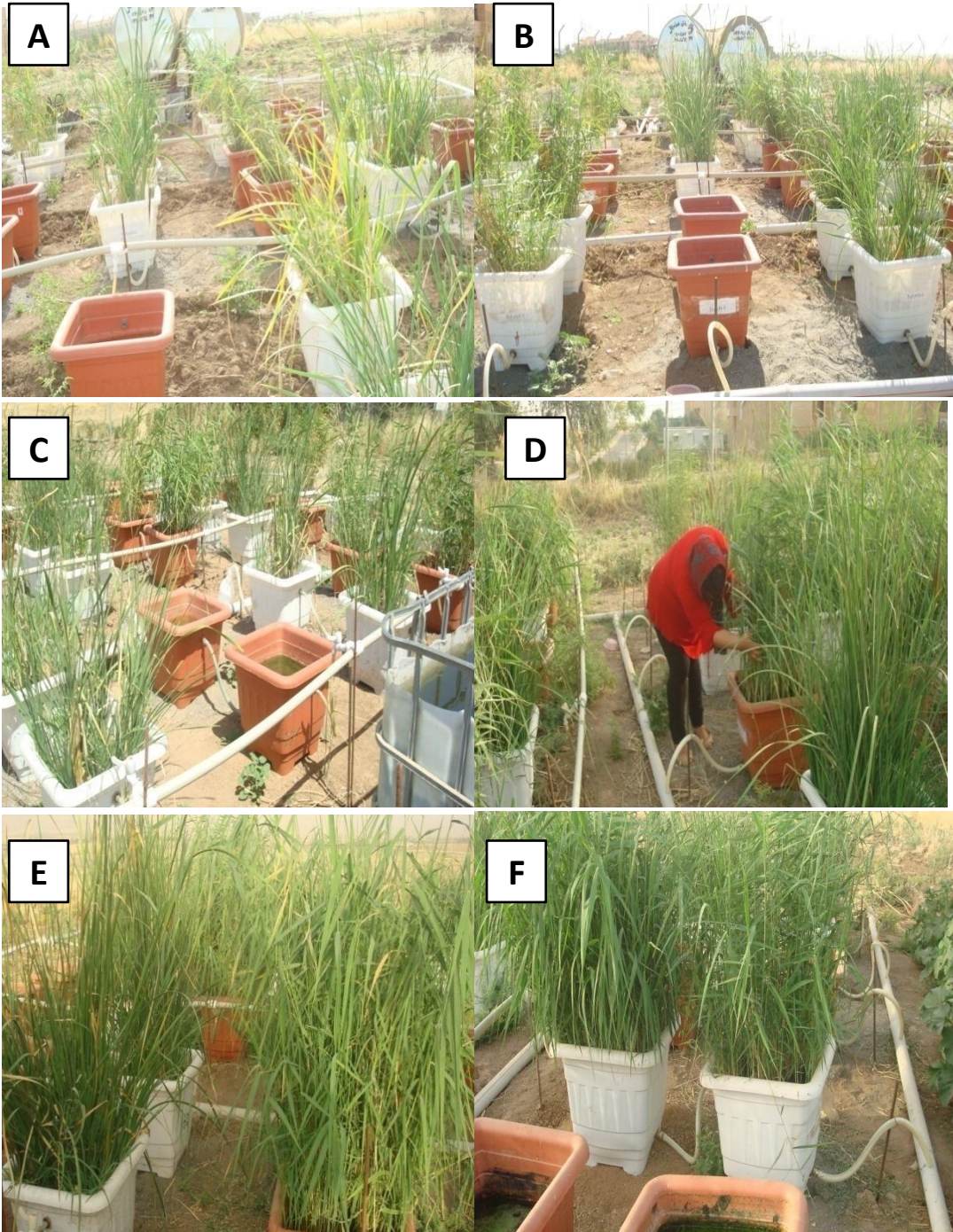
### **Filtration Media**

The media used in the project consist of the (sand and gravel). The sand (2.0 mm diameter) and gravel (20mm diameter) were prepared previously by washing to remove all litter and particles. Selected the sand 2.0 mm diameter and gravel 20 mm diameter to combination and supported the roots macrophytes. To obtain the best effluent flow-rate, the effective size sand was passed through a 2.0 mm sieve [10].

### **Macrophyte transplantation**

Two aquatic plants (*T. angustifolia*) local name Laban and (*Ph. australis*) local name Qamishli Barek were collected to the project near the Faculty of Agricultural Sciences/ Sulaimani University IKR. They were used to purify the wastewater in the hybrid constructed wetland (plate 9). After transplantation in April 25, 2013 (6 plants per one constructed wetland), the plants were left to stand for 50 days, the time required for the adaptation and stabilization of young plants with their new place[11]. Finally purified wastewater samples from the outlet of hybrid

constructed wetland after treatment collected every 15 days and taken to the laboratory to be prepared for analysis, as shown in (plate 10). Furthermore, in the remaining days the treated wastewater from the outlet of hybrid constructed wetland collected in plastic pipe discarded far away from the project area for avoiding contamination of the area, as shown in (plate 11).



**Plate (9):** Different stage of growth for *Typha angustifolia* and *Phragmites australis* in hybrid constructed wetlands. (A)Growth macrophyte after 50 days, (B) Growth macrophyte after 70 days, (C) Growth macrophyte after 90 days, (D) Growth macrophyte after 100 days, (E, F) the end of experiment after 130 days



**Plate (10): Collection of wastewater samples after treatment.**



**Plate (11): The total outlet of the project**

## **Results and discussion**

### **Heavy Metals Removal**

#### **Iron-Fe ( $\text{mg L}^{-1}$ )**

Iron occurs as one of the principal chemical constituents in water and it also plays an important role in plant respiration and photosynthetic reactions, under anaerobic condition, the content of  $\text{Fe}^{2+}$  could be several  $\text{mg/l}$ , particularly in ground water and wastewater, while in most aerobic surface waters the concentration seldom exceeds  $0.3 \text{ mg/l}$  [12].

Table 1 shows a significant decrease in the mean value of iron concentration in treated wastewater which is ( $P>0.01$ ), using macrophyte *T. angustifolia* and *Ph. australis* in hybrid constructed wetlands. The mean

value of iron concentrations of wastewater storage tanks during the study period is 1.192mg L<sup>-1</sup>. This result is higher than those results obtained by [13] on Dohuk wastewater, [14] on Hawler wastewater and [11] on main sewage channels of Sulaimani City.

Table 1 also shows a significant decrease for the mean value of iron concentration in treated wastewater after sedimentation that is (p>0.01) using macrophytes. The *T. angustifolia* was planted in both HCW (H&V and V&H) which cause the mean values of iron concentrations to decrease to 0.624-0.519mg L<sup>-1</sup> respectively. The *Ph. Australis* was planted in both HCW (H&V and V&H) which decrease the mean value of iron concentration to 0.700-0.696mg L<sup>-1</sup>. This reveals the ability of *T. angustifolia* that is higher to removal iron concentration compared to *Ph. australis*. The effect of both macrophytes for decreasing iron concentration is higher but the greater ability back to *T. angustifolia* to removal iron concentration, high removal this may be related to root system of *T. angustifolia*[15]. The table also shows the design HCW (V&H) without plants decrease mean value of iron concentration 1.049mg L<sup>-1</sup>, while the design HCW (H&V) without plants decrease mean value iron concentration 1.068mg L<sup>-1</sup>. It is estimated from the study that the design HCW (V&H) without plants better than the design HCW (H&V) without plants for decreasing mean value of iron concentration effect back to the wastewater through the wetland vertically.

**Table (1):** The mean values of the Iron (Fe) (mg L<sup>-1</sup>) measured from outlet point for untreated and treated wastewater with *T. angustifolia* and *Ph. australis* in HCWS during the studied period.

Treatments ( Sample of effluent)	Date of Experiment – 2013						Mean
	June 15	July 01	15	August 01	15	September 01	
Untreated raw wastewater	1.171	1.095	1.161	1.186	1.186	1.352	<b>1.192</b>
Effluent of Sedimentation unit	1.152	1.088	1.115	1.173	1.159	1.218	<b>1.151</b>
Control-hybrid constructed wetland (Horizontal & Vertical)	1.052	1.056	1.027	1.048	1.099	1.125	<b>1.068</b>
<i>T. angustifolia</i> in hybrid constructed wetland (Horizontal & Vertical)	0.679	0.679	0.632	0.580	0.574	0.599	<b>0.624</b>
<i>Ph. australis</i> in hybrid constructed wetland (Horizontal & Vertical)	0.670	0.732	0.584	0.611	0.852	0.750	<b>0.700</b>
Control-hybrid constructed wetland (Vertical & Horizontal)	1.033	1.047	1.015	1.009	1.094	1.099	<b>1.049</b>
<i>T. angustifolia</i> in hybrid constructed wetland (Vertical & Horizontal)	0.522	0.597	0.518	0.508	0.424	0.547	<b>0.519</b>
<i>Ph. australis</i> in hybrid constructed wetland (Vertical & Horizontal)	0.703	0.687	0.646	0.632	0.810	0.697	<b>0.696</b>
Mean	<b>0.873</b>	<b>0.872</b>	<b>0.837</b>	<b>0.843</b>	<b>0.900</b>	<b>0.923</b>	<b>0.875</b>
LSD	Treatment		Period		Interaction		
	<b>0.05</b>	<b>0.01</b>	<b>0.05</b>	<b>0.01</b>	<b>0.05</b>	<b>0.01</b>	
	<b>0.047</b>	<b>0.063</b>	<b>0.041</b>	<b>0.054</b>	<b>0.116</b>	<b>0.153</b>	

**Copper**

WHO, 2006 demonstrates that; Copper is a reddish metal that occurs naturally in rock, soil, plants, animals, water, sediment and air. Copper compounds are used as agricultural pesticides and to control the

spread of algae. [16] and [17] stated that copper is an essential element for plants and animals metabolism. It is compounds are widely distributed in nature including surface water and some groundwater. Copper is widely distributed in nature in Free State [18] It readily forms a chelate with humic acids in the organic fraction of the soil and may be involved in providing Cu to the surface of the root [19].

In the present study, the total recorded mean value of Cu concentration of storage raw wastewater is 0.636mg L<sup>-1</sup> as shown in Table 5.19. This value is agreement with those results obtained by [20] and [11], but it is higher than that obtained by [13] of Dohuk wastewater. This may be due to the fact that the main sewage canal at Bacrajw village always contains high pollutants.

Table 2, shows the significant (P>0.01) decrease of the mean value of copper concentrations in treated wastewater using plants. This is achieved by using macrophytes *T. angustifolia* and *Ph. australis* in hybrid constructed wetlands. The *T. angustifolia* was planted in both HCW (H&V and V&H) which result in decreasing the mean values of copper concentrations from 0.472 to 0.444 mg L<sup>-1</sup>. The *Ph. australis* was planted in both HCW (H&V and V&H) which cause decreasing the mean values of copper concentrations from 0.497 to 0.473 mg L<sup>-1</sup>. This result reveals the ability of *T. angustifolia* to decreasing copper concentration that is higher than of *Ph. australis*. While the effect of both macrophytes in decreasing the mean values of copper concentration is higher but greater effects back to *T. angustifolia* this may be correlated to the capacity of *T. angustifolia* to absorb Cu.

From the same table, the design HCW (V&H) without plants decreases the mean value of copper concentration to 0.590mg L<sup>-1</sup>, while the design HCW (H&V) without plants decreases the mean value of copper concentration to 0.616mg L<sup>-1</sup>. In the present study, the design HCW (V&H) without plants is better than the design HCW (H&V) without plants in decreasing the mean value of copper concentration. This effect back to the wastewater through the wetland vertically.

## Cadmium

Cadmium is commonly being associated with Zinc in Carbonate and sulfide ores [18]. Cadmium is present in the wastewater from metallurgical alloying, ceramics, electroplating, photography, pigment works, textile printing, chemical industries and lead mine drainage. Cadmium is removed from wastewater by precipitation or ion exchange [21].

The mean value of Cd concentration of wastewater is 0.058 mg L<sup>-1</sup> in the Table 3. This value is less than that obtained by [13] on Dohuk wastewater. This is may be due to multi-sources of cadmium which come from industrial region, fertilizer, pesticides uses in farmland. For treated wastewater by the plants after sedimentation generally, showed in the Table 3 a significant (P>0.01) decrease in mean value of cadmium concentrations in treated wastewater by the plants, when used macrophyte *T. angustifolia* and *Ph. australis* in hybrid constructed wetland. When used macrophyte the *T. angustifolia* was planted in both HCW (H&V and V&H) the decrease mean values cadmium concentrations to 0.033-0.031mg L<sup>-1</sup> respectively, and *Ph. australis* are planted in both HCW (H&V and V&H) the decrease mean values cadmium concentrations to 0.035-0.033mg L<sup>-1</sup> respectively, this revealed the ability of *T. angustifolia* to decrease-

**Table (2):** The mean values of the Copper (Cu) (mg L<sup>-1</sup>) measured from outlet point for untreated and treated wastewater with *T. angustifolia* and *Ph. australis* in HCWS during the studied period.

Treatments ( Sample of effluent)	Date of Experiment – 2013						Mean
	June 15	July 01	15	August 01	15	September 01	
Untreated raw wastewater	0.453	0.635	0.536	0.666	0.699	0.826	<b>0.636</b>
Effluent of Sedimentation unit	0.435	0.625	0.510	0.643	0.976	0.805	<b>0.665</b>
Control-hybrid constructed wetland (Horizontal & Vertical)	0.392	0.507	0.467	0.526	0.895	0.910	<b>0.616</b>
<i>T. angustifolia</i> in hybrid constructed wetland (Horizontal & Vertical)	0.336	0.448	0.352	0.403	0.656	0.638	<b>0.472</b>
<i>Ph. australis</i> in hybrid constructed wetland (Horizontal & Vertical)	0.342	0.454	0.393	0.437	0.682	0.676	<b>0.497</b>
Control-hybrid constructed wetland (Vertical & Horizontal)	0.389	0.503	0.457	0.519	0.896	0.779	<b>0.590</b>
<i>T. angustifolia</i> in hybrid constructed wetland (Vertical & Horizontal)	0.344	0.420	0.322	0.376	0.612	0.589	<b>0.444</b>
<i>Ph. australis</i> in hybrid constructed wetland (Vertical & Horizontal)	0.364	0.449	0.376	0.398	0.656	0.598	<b>0.473</b>
Mean	<b>0.382</b>	<b>0.505</b>	<b>0.426</b>	<b>0.496</b>	<b>0.759</b>	<b>0.727</b>	<b>0.549</b>
LSD	Treatment		Period		Interaction		
	<b>0.05</b>	<b>0.01</b>	<b>0.05</b>	<b>0.01</b>	<b>0.05</b>	<b>0.01</b>	
	<b>0.054</b>	<b>0.072</b>	<b>0.047</b>	<b>0.062</b>	<b>0.132</b>	<b>N.S</b>	

cadmium concentration higher than of *Ph. australis*. While the effect of both macrophytes for decreasing Cd concentration mean values were decreased slightly but the larger effects back to *T. angustifolia* this may be this correlated with combination effect of *T. angustifolia* together in Cd absorbed.

As shown in the results design HCW (V&H) without plants the mean value of cadmium concentration decrease to 0.041mg L<sup>-1</sup>, while the design HCW (V&H without plants the mean value of cadmium concentration decrease to 0.042mg L<sup>-1</sup>. Show in the present study the design HCW (V&H) without plants is better than the design HCW (V&H) without plants in decreasing the mean value of cadmium concentration. This effect is due to vertical the wastewater through the wetlands.

**Table (3):** The mean values of the Cadmium (Cd) (mg L<sup>-1</sup>) measured from outlet point for untreated and treated wastewater with *T. angustifolia* and *Ph. australis* in HCWS during the studied period.

Treatments ( Sample of effluent)	Date of Experiment – 2013						Mean
	June 15	July 01	15	August 01	15	September 01	
Untreated raw wastewater	0.039	0.042	0.029	0.083	0.055	0.098	<b>0.058</b>
Effluent of Sedimentation unit	0.034	0.037	0.021	0.074	0.044	0.084	<b>0.049</b>
Control-hybrid constructed wetland (Horizontal & Vertical)	0.030	0.035	0.017	0.069	0.038	0.063	<b>0.042</b>
<i>T. angustifolia</i> in hybrid constructed wetland (Horizontal & Vertical)	0.026	0.028	0.009	0.059	0.026	0.051	<b>0.033</b>
<i>Ph. australis</i> in hybrid constructed wetland (Horizontal & Vertical)	0.028	0.031	0.011	0.060	0.027	0.054	<b>0.035</b>
Control-hybrid constructed wetland (Vertical & Horizontal)	0.030	0.034	0.016	0.067	0.037	0.062	<b>0.041</b>
<i>T. angustifolia</i> in hybrid constructed wetland (Vertical & Horizontal)	0.024	0.026	0.008	0.056	0.024	0.049	<b>0.031</b>
<i>Ph. australis</i> in hybrid constructed wetland (Vertical & Horizontal)	0.029	0.026	0.009	0.057	0.026	0.051	<b>0.033</b>
Mean	<b>0.030</b>	<b>0.033</b>	<b>0.015</b>	<b>0.065</b>	<b>0.034</b>	<b>0.064</b>	<b>0.040</b>
LSD	Treatment		Period		Interaction		
	<b>0.05</b>	<b>0.01</b>	<b>0.05</b>	<b>0.01</b>	<b>0.05</b>	<b>0.01</b>	
	<b>0.004</b>	<b>0.005</b>	<b>0.003</b>	<b>0.004</b>	<b>0.009</b>	<b>0.012</b>	

### Lead

Lead is the element in the environment, which does not biodegrade or decay [22]. Lead can cause health problems to human beings, particularly, children. It accumulates in the body and can build to toxic level under continuous exposure [23]. In the present investigation, Pb concentration in the storage raw wastewater was 0.354mg L<sup>-1</sup> in the Table 4, this high value may due to the fact that they received wastewater and other pollutants from all parts of the residential places [13]. Generally, lead concentration in untreated wastewater beyond maximum permissible level of Pb in irrigation water, as stated by [24] which was (50µg.l<sup>-1</sup>), and [25] which was (65µg.l<sup>-1</sup>).

While after sedimentation treated wastewater by the plants generally, showed in the Table 4 a significant (P>0.01) decrease in the mean values of lead concentrations in treated wastewater, by the plants. When the *T. angustifolia* was planted in both HCW (H&V and V&H) the mean values of lead concentrations decrease to 0.224-0.203mg L<sup>-1</sup> respectively. As *Ph. Australis* was planted in both HCW (H&V and V&H) the mean values of lead concentrations decrease to 0.223-0.225mg L<sup>-1</sup> respectively. This result reveals the ability of *T. angustifolia* to decreasing lead concentration is less high than of *Ph. australis*. While the effect of both macrophyte to decreasing the mean values of lead were decreased slightly but the larger effects back to *T. angustifolia*. [26] Found that the first macrophyte *T. angustifolia* has the higher removal ability than the

other and this due to that they have wide and long root system, most lead was accumulated in root cells around vacuoles and slowly transported to leaves. In the results show the design HCW (V&H) without plants the mean value of lead concentration decrease to 0.288 mg L<sup>-1</sup>, while the design HCW (H&V) without plants

the mean value lead concentration decrease to 0.300mg L<sup>-1</sup>. Show in the present study the design HCW (V&H) without plants is better than the design HCW (H&V) without plants to decline mean value of lead concentration effect back to the wastewater through the wetland vertically.

**Table (4):** The mean values of the Lead (Pb) (mg L<sup>-1</sup>) measured from outlet point for untreated and treated wastewater with *T. angustifolia* and *Ph. australis* in HCWS during the studied period.

Treatments ( Sample of effluent)	Date of Experiment – 2013						Mean
	June 15	July 01	15	August 01	15	September 01	
Untreated raw wastewater	0.290	0.383	0.268	0.435	0.427	0.324	<b>0.354</b>
Effluent of Sedimentation unit	0.268	0.358	0.240	0.412	0.399	0.322	<b>0.333</b>
Control-hybrid constructed wetland (Horizontal & Vertical)	0.237	0.320	0.192	0.375	0.378	0.297	<b>0.300</b>
<i>T. angustifolia</i> in hybrid constructed wetland (Horizontal & Vertical)	0.185	0.257	0.123	0.304	0.284	0.189	<b>0.224</b>
<i>Ph. australis</i> in hybrid constructed wetland (Horizontal & Vertical)	0.131	0.272	0.127	0.296	0.325	0.190	<b>0.223</b>
Control-hybrid constructed wetland (Vertical & Horizontal)	0.217	0.305	0.186	0.367	0.368	0.286	<b>0.288</b>
<i>T. angustifolia</i> in hybrid constructed wetland (Vertical & Horizontal)	0.173	0.231	0.077	0.284	0.285	0.171	<b>0.203</b>
<i>Ph. australis</i> in hybrid constructed wetland (Vertical & Horizontal)	0.181	0.245	0.114	0.331	0.313	0.171	<b>0.225</b>
Mean	<b>0.210</b>	<b>0.296</b>	<b>0.166</b>	<b>0.350</b>	<b>0.347</b>	<b>0.244</b>	<b>0.269</b>
LSD	Treatment		Period		Interaction		
	<b>0.05</b>	<b>0.01</b>	<b>0.05</b>	<b>0.01</b>	<b>0.05</b>	<b>0.01</b>	
	<b>0.016</b>	<b>0.021</b>	<b>0.01</b>	<b>0.018</b>	N.S	N.S	
			<b>4</b>				

**Conclusion:**

1. Results from the study show that hybrid constructed wetlands (Vertical & Horizontal) can remove more pollutant as compared with hybrid constructed wetlands (Horizontal& Vertical)
2. Results show that (**T .angustifolia** and **Ph. australis**) planted in hybrid constructed wetlands have more significant role in purifying wastewater.
3. The couple macrophyte under this investigation show a clear capability in purifying wastewater from the heavy metals such as (Fe, Cu, Cd and Pb) bioaccumulations and seems to improve the quality of treated water from very bad to good water for irrigation.

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