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Study the Control of Nutrients Removal from Wastewater by Using Local Plants in Constructed Wetlands as Tertiary Treatment

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Abstract

This paper presents the results of using a pilot-scale-constructed wetland as a tertiary treatment to the domestic wastewater by using local plants in Syria, aiming to achieve the Syrian legal standards of phosphorus and nitrogen emissions.

This pilot plant consisted of tow types of wetlands.The emerged plants are placed in 3tanks and followed by 3 tanks of free-floating plant, daily estimating the treatment of24.m3/day of effluents. The effluents were circulated in a vertical subsurface flow through a porous matrix of thick sand and gravel, in which the roots of the Arundo donax and Cattail (Typha sp.) and Bottomos (locally species Reed) were fixed. Monitoring of the pilot plant was performed through biological analyses. The flow bypassing through free-floating plant tanks will support removing the nutrients. The system offer a good degree of pollutant efficiency removal, especially for phosphorus (45% medium), TKN (80% medium), and NH4–N (60% medium).

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Keywords

Constructed wetland. Local plants. Tertiary system. Phosphorus. Nitrogen

1. Introduction

. In the continual search for a simple and inexpensive wastewater treatment system, the natural systems are the latest discovery, and this treatment process involved in the natural systems include: sedimentation , filtration , gas transfer , adsorption ,ion exchange , chemical precipitation , chemical oxidation and reduction , and biological conversions [1]

Considering this profile, to use these constructed wetlands as a tertiary treatment.

-due to its low implementation and maintenance costs.

-simple operation, and high efficiency of pollutant removal.[2]

According to[3] these constructed wetlands are formed by an artificial bed, usually using a sand and gravel matrix plant roots and microorganisms are constructing in this matrix as the biofilm.

The main agents of pollutant removal, are (roots, leaves, and stemps)of the plants, the microorganisms, and the support layer in the constructed wetlands. According to Sousa et al. (2004). [4]

The aquatic macrophytes frequently used in constructed wetland systems are either the emergent or floating types. According to Gerber (2004).

The emergent macrophytes have a more highly resistant supporting tissue than those of the floating macrophyte variety; this causes the first type to exhibit a superior capacity to remove and retain nutrients. According to Giovannini(1997).

For that we used in our pilot plant the macrophytes, popularly called *Arundo donax* and Cattail (Typha subulata),Bottomos and the floating macrophyte called Lemna,which are most commonly used in the constructed wetlands in Syria.

According to Sakadevan and Bavor (1998) ,The capacity to absorbing phosphorus from industrial, agricultural can raise if the high levels of different types of oxides (calcium, magnesium and iron) present in the slag.

The constructed wetlands are effective in the removal of several kinds of pollutants: suspended solids, BOD, COD, hydrocarbons, pathogenics, nitrogen, phosphorus, and heavy metals According to ITRC 2003; Matagi et al. 1998.

Because it has used in this pilot-scale a vertical flow, that will give the chance the oxygen to be transferred within the constructed wetlands by convection, rhizomes and diffusion.

According to IWA (2000), In the constructed wetlands, the nitrogen undergoes many transformations.

First, the organic nitrogen is biologically transformed into ammoniacal nitrogen through ammonification process (or called mineralization).

Secondly, according to Curia (2003),the oxidation of ammonia into nitrite and then into nitrate through nitrification process ,which promoted by the action of the nitrifying bacteria, of the genus Nitrossomonas and Nitrobacter.

This nitrification is followed by denitrification, occurs in the anaerobic and anoxic zones,and involving energy reduction, when electrons are added to the nitrate, producing gaseous nitrogen (N2), nitrous oxide (N2O), or nitric oxide (NO).

The removal of phosphorus in the constructed wetlands occurs through chemical precipitation, adsorption, assimilation of vegetables and biofilms formed in the substrate, and the radicular system of the vegetation. The amount of phosphorus depends on its concentration in the water associated with the biochemical soil processes, which include adsorption/desorption, precipitation, mineralization of the organic phosphorus and diffusion of the phosphorus from the soil, According to Matagi et al. 1998.

Constructed wetlands have been designed and classified by the type of macrophytic growth, further classification is usually based on the water flow regime (Fig. 1). (Fig. 2).

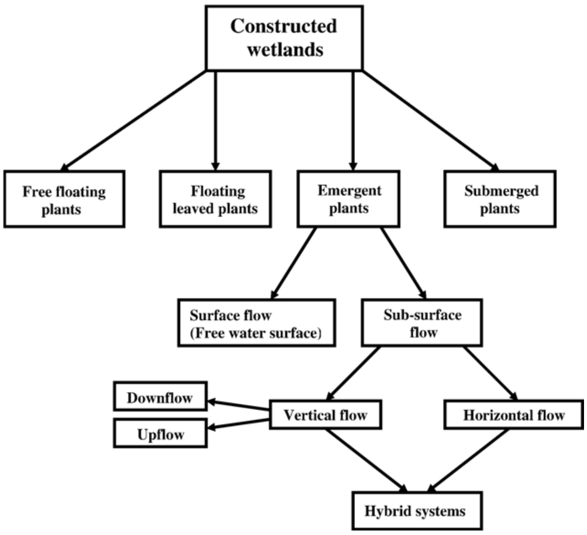

Figure 1. Classificationof constructed wetlands for wastewater treatment (Vymazal, 2001) ,J. Vymazal /Science of the Total Environment 380 (2007) 48–65.

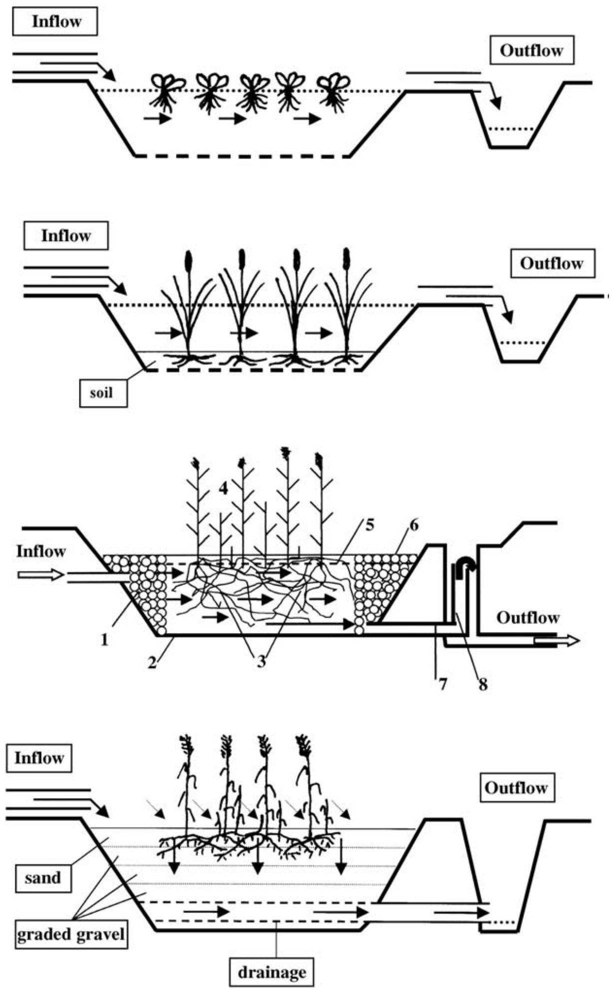

Figure 2. Types of Constructed wetlands for wastewater treatment (from top to bottom): CW withfree-floating plants ,CW with free water surface and emergent macrophytes ,CWwith horizontal sub-surface flow ,CW with vertical sub-surface flow ,based on(Vymazal,2001)

But it is important to know, that VSSF CWs remove more ammonia-N than FWS and HSSF wetlands due to the high oxygenation of VSSF beds

Vertical-flow constructed wetlands remove successfully ammonia-N but very limited denitrification takes place in these systems.

On the other hand, horizontal-flow constructed wetlands provide good conditions for denitrification but the ability of these systems to nitrify ammonia is very limited.

(all of Australia, Austria, China, Denmark, France, Germany, Ireland,

Poland, Norway, The Netherlands, Turkey, UK reached a high total Nitrogen removal by using VSSF = vertical sub-surface flow). Based on Vymazal 2001,2005.

Therefore, we have chosen the vertical- alternating –flow (in the pilot scale) to allow the oxygen enter through the pores of the matrix and give bigger chance for removing the total nitrogen .fig(3)

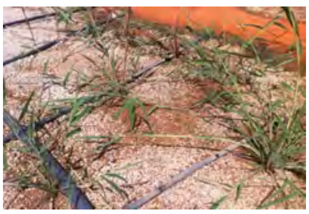

Figure 3. vertical-alternating –flow (in the pilot scale)

2. Species of utilized plants in contracted wetlands:

1.Amphibious plants or pop Amphibous or emergent plants.
Plants adapted for life in shallow water as they remain roots and lower parts submerged in water, while most of the total vegetative rise above the water surface, most notably in Syria are:
• Arundo donax
• Cattail (Typha latifolia)
• Scirpus litoralis
Arundo donax
Name; Arundo donax L.
Family: Gramineae (Poaceae).
Common name: Giant reed, Spanish cane, Phragmate .fig (4)

Figure 4. Phragmate(local emerged plant)

Arundo donax spread widely on the edge of canals and drainage channels in particular and on the edge of lagoons and marshes, and on the beach.
It is known a multiple used as a pillar for the climbing plants and to build Trellis, in the manufacture of hook fishing is used in the manufacture of brooms, and is a good source for the paper industry, and is used in Italy in the manufacture of artificial silk Rayon, in addition it used as firewood.
This can in the feed industry from its young leaves [5] [6]
According to plant in soil stabilization, and is used as barriers to break the intensity of the wind, is also used to purify water, and utilized in the construction of its market and in the carpet industry [7], as utilized in the manufacture of grain sorties dye [8]
Typha latifolia:
Name: Typha latifolia L.
Family: Typhaceae.
Common name: Cattail.fig(5)

Figure 5. Typha (local emerged plant)

Used its rhizomes and roots which are rich of protein as food when it s dried and powdered and added to the flour for the bread and biscuits [20] and its pollens which are rich in protein can be added to the flour, which used in the manufacture of some types of bread and porridge with high nutritional value [9].

Its roots used medically in the treatment of tumors, it is also generating and booster milk, and powdered roots are used after mixing with oil in the form of compresses for the treatment of infected wounds and skin ulcers, and the boiled leg can be used in the treatment of whooping cough [10]

Typha plays an important environmental role in the water bodies by playing a role to prevent the arrival of eroded soils to water bodies, and a habitat for many organisms, particularly for the birds, which often make their nests from the fluffy fruits of Typha, and used in the manufacture of paper, straw chairs, and hats, and silk Industrial (Rayon), and fruits are used as a substitute for feathers in the manufacture of pillows [11].

3. Botomos:

Is an emerged aquatic local plant, particularly frequent presence around the lakes and especially the Syrian Lake Zarzar, and has given good results in the wastewater treatment that were supplied directly on these lakes, which insisted to implementing the testing in local laboratories and get results very acceptable in wastewater treatment. Fig(6)

Figure 6. Botomos (locale merged plant)

4. Floating Hydrophytes:

Lemna minor. fig (7).

Family: Lemnaceae.

Common name: Lesser duckweed.

Figure 7. Lemna minor (floated local plant).

These plants remain floating on the surface of the water, Has a shape like lentils bloom in summer frequent presence in stagnant fresh water on the banks of rivers and lakes and on the wet rocks [12], the most species presence in Syria Lemna minor.

5. Methods and Materials:

The components of pilot scale:

The dimensions of this pilot have designed and selected by considering the recommendations of Germany Code for wastewater treatment by constructed wetlands. Table (1), and adopting the locally circumstances to extract the operational parameters for nutrients removal from the Syrian wastewater which to be treated by constructed wetlands as tertiary treatment and consisting the technological treatment line, as shown in Figure (8).

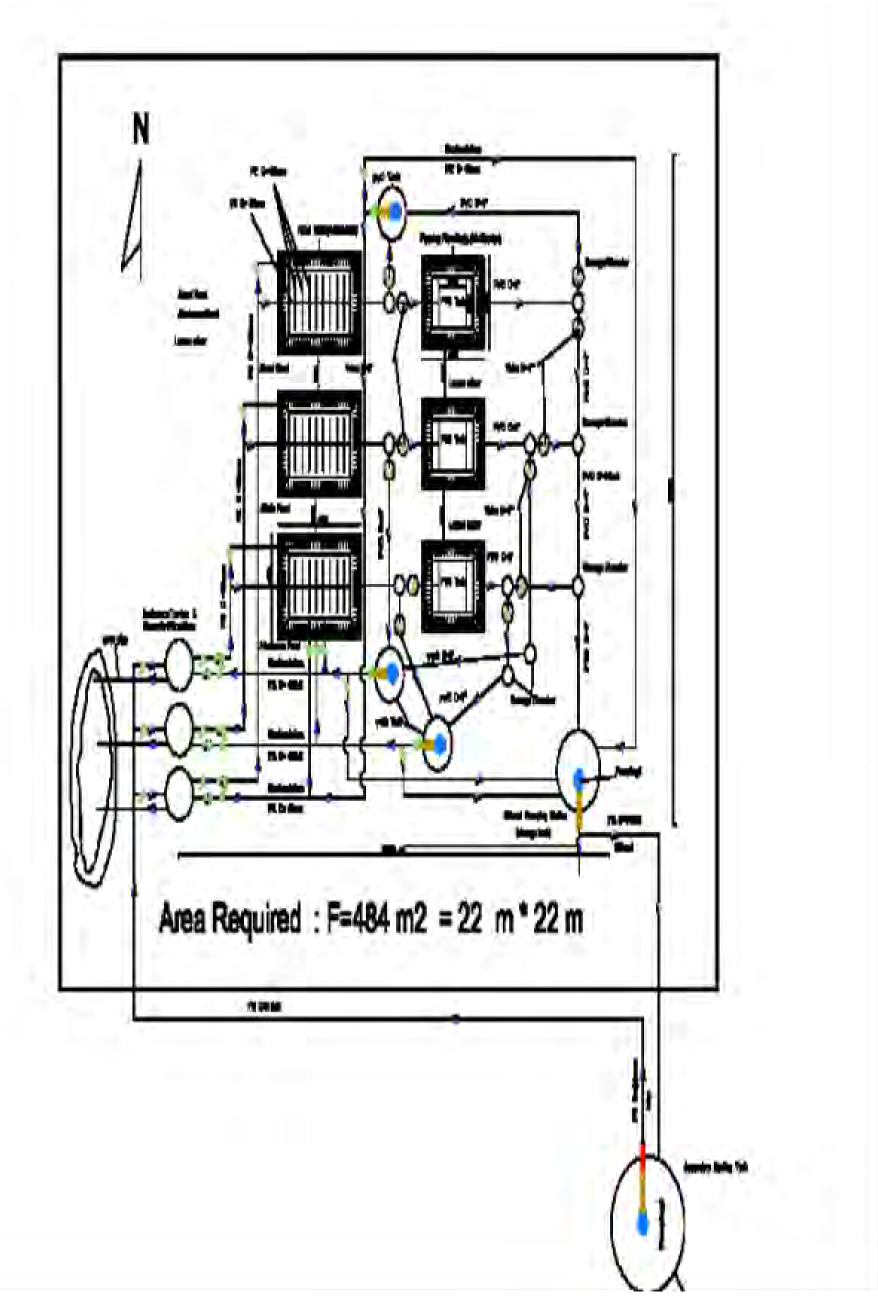

Figure 8. thetechnological treatment line of the pilot-scale.

Table 1. Germany Code for wastewater treatment by constructed wetlands.

Parameter	Unit	Value
Filtration time between tow consecutive effluents	h<12 c	>6/2
	h<12 c	>3/2
Effluent load	l/m2.min	>6

Pilot –scale activation:

The equipment of this pilot are implemented and planted the chose plants during November 2011, in considering that these plants need at least a month until its rhizome has been completed, which has an effective role in the treatment process. The inflow water is passed to the emerged plants from the secondary treated water tanks, thus this water won't be passed to Lemna's tanks because mostly they die in winter, then will start to grow and cover the entire surface of its tanks in the spring season, around 14 May 2012, but it is recognized that the concentrations of most components in outflow water has not changed during the first three months, due to hibernate, which passes the plant during the winter, and begins appearance change in the results of treatment on 14 March, where this treatment gave satisfactory results in terms of removing nitrogen

(TN = 75%, N-NH4 = 50%)

The results of removing phosphorus was unsatisfactory (PO4 = 25%)

This is why we must apply some of the techniques that have been used in this area to improve the nutrient removal, where we found that recycling a percentage the outflow of the secondary treated wastewater, like (10%) of the total inflow load to this pilot-scale, as refereed in the study According to Kantawanichkul and Neamkam, 2001. It is possible in this way to raise the organic load in the inflow water and also to raise the oxygen concentration inside the central filter around the roots net and thus increases the activity of organisms in aerobic conditions for nitrification process , which may help in improving the efficiency of pollutants removal in these conditions ,According to kantawanichkul et al., 2001; Sun et al., 2003. The total inflow water as a hydraulic load to this pilot-scale is($24m^3\backslash$ h),but that is pumped as a vertical surface flow ,and this hydraulic load can be divided into three equal loads, each one is 8m3/h, and this will be pumped three times a day, then the pumping will stop for three hours between each time.

The first recirculation ratio is (produced from Lemna tanks) Q1=10%Q=0.1Q=$0.8m^3\backslash$h, added to the inflow water from secondary treatment will equal

Q2=90%Q=7.2 $m^3\backslash$h, for that the total inflow water to the pilot-scale will be Q=Q1+Q2=0.8+7.2 =$8m^3\backslash$h.

The circulation ration (10%), the second ratio is 20%, for that the total inflow water will be performed by this equation

Q=Q1+Q2=20%Q +80%Q =1.6 +6.4 =$8m^3\backslash$h.

Note: that we will continue proceeding different recirculation ratios until we cannot find any changes in the samples results, then we can choose the best ratio which gives the best nutrients removal.

But in order to get the best removal results, it is suggested to change the surface load , and implement the same recirculation ratios (10%,20%) on each different loads. For that we choose two different surface loads ($6m^3/m^2$ h,$4m^3/m^2$ .h)respectively ,and each one will be supplied for a week time but for each one of these loads will implement a recirculation ration (10% of Q, and 20% of Q) respectively, and also for a week time of each ratio.

The equipment and experiments:

To measure BOD5, we used JANATECH – CL – 400 WTW TS 60612

And the equipment WTW oxi top Ts 12

To measure COD.

The digestor Hach cod rector Foss 2006 to measure the total nitrogen and ammonia.

And for pH we used WTW pH 330.

We considered the standard colorimetric methods APHA (1998) to measure the total phosphorus ,by using (Secomam DR-Spectrophotomete 2010) and also to measure nitrate .

The results from each recirculation ratio (10%, 20 %,..) should be compared with the Syrian standards for irrigation (2752).fig (9)

Figure 9. the three species of emerged used plants in the pilot-scale after three months ofplanting.

The results and discussions:

To evaluate the results of this experimental project, but the results were divided into three steps :

The first step: included the results of the first surface load (8 m3/m2/h) and implementing tow circulation ratios (10%, 20%).

The second step: included the results of the second surface load (6 m3/m2. h) and implementing the same recirculation ratios.

The third: included the results for ($4m^3/m^2$ .h) surface load with the same circulation ratios.

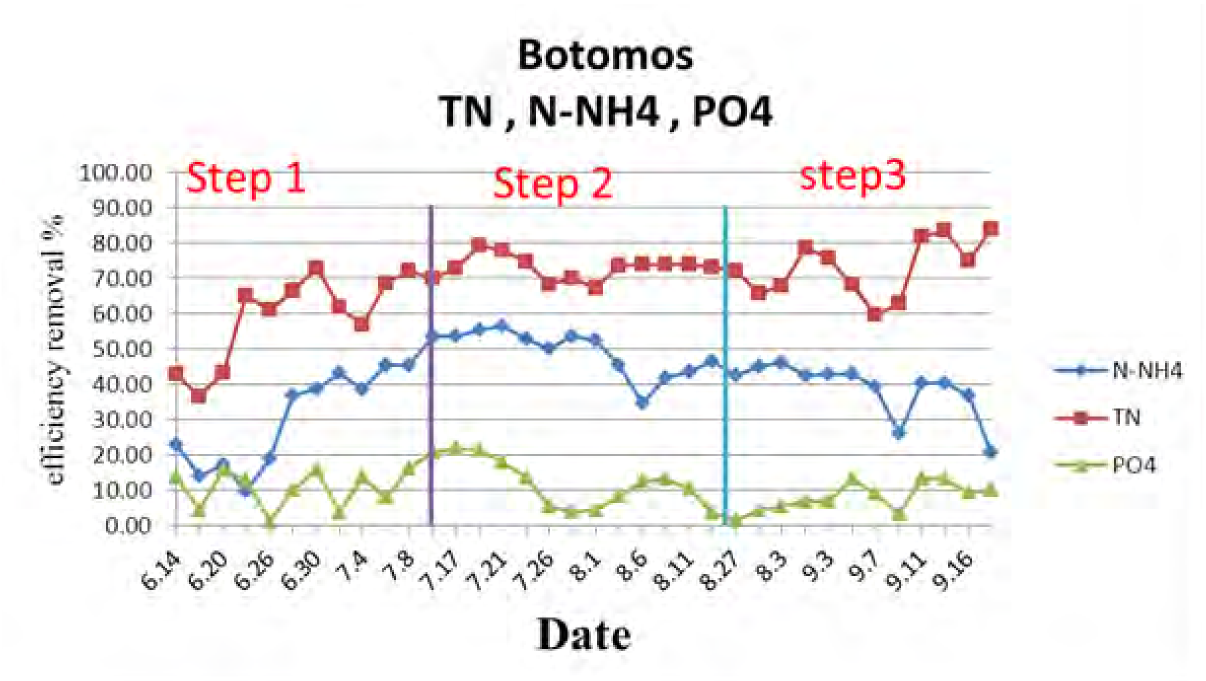

Figure 10. Effeciency removal of TN,N-NH_4,PO_4 IN Botomos tanks during three surface loads (8,6,4)m^3/m^2.h and tow circulation ratios(10%,20%) for each load and for one week time for each different load .

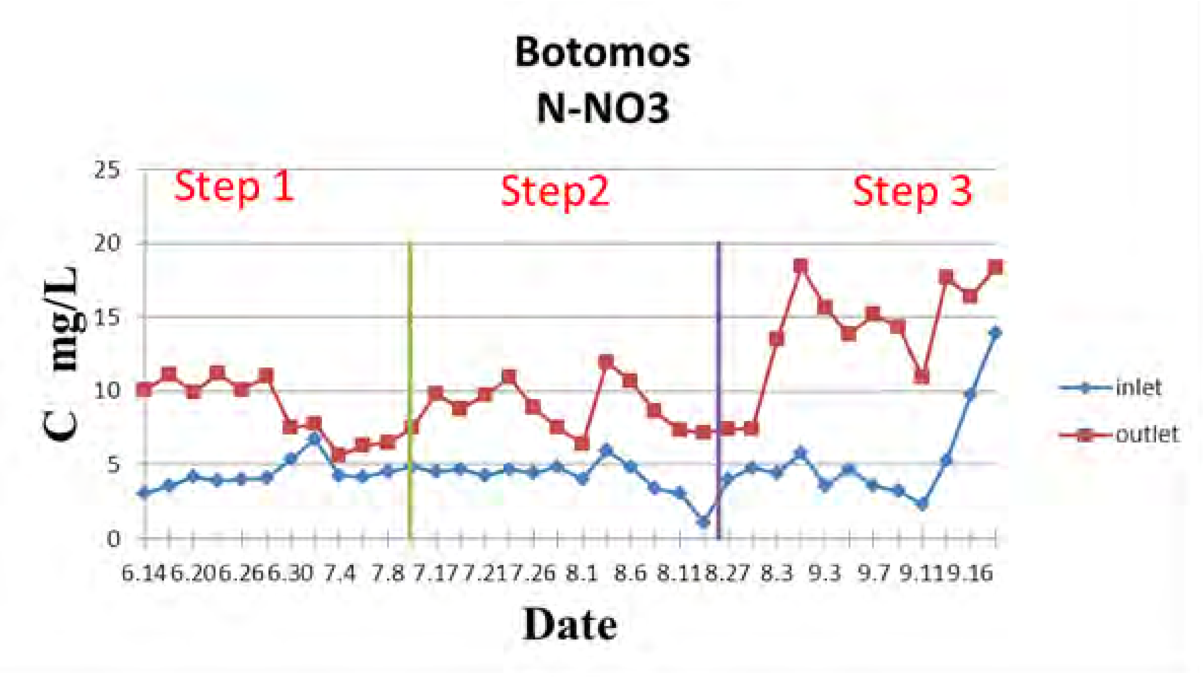

Figure 11. Efficiency removal of $N\text{-}NO_3$ IN Botomos tanks during three surface loads(8,6,4)m^3/m^2.h and tow circulation ratios (10%,20%) for each load and for one week time for each different load

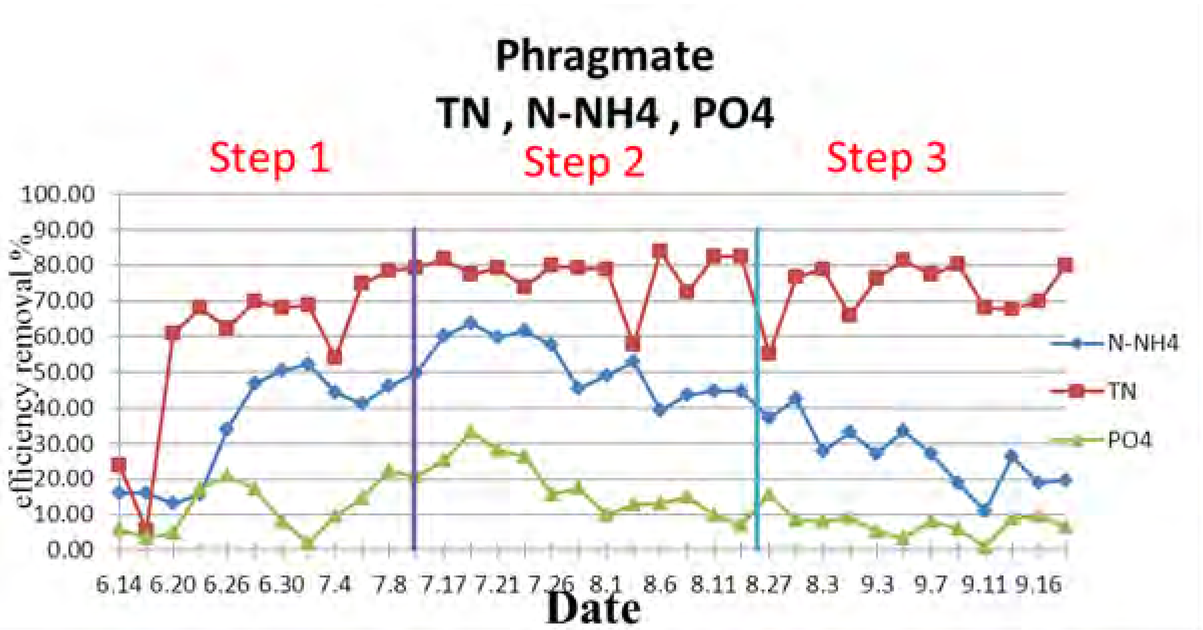

Figure 12. Efficiency removal of TN,$N\text{-}NH_4$,PO_4 IN Phragmate tanks during three surface loads (8,6,4)m^3/m^2.h and tow circulation ratios(10%,20%) for each load and for one week time for each different load .

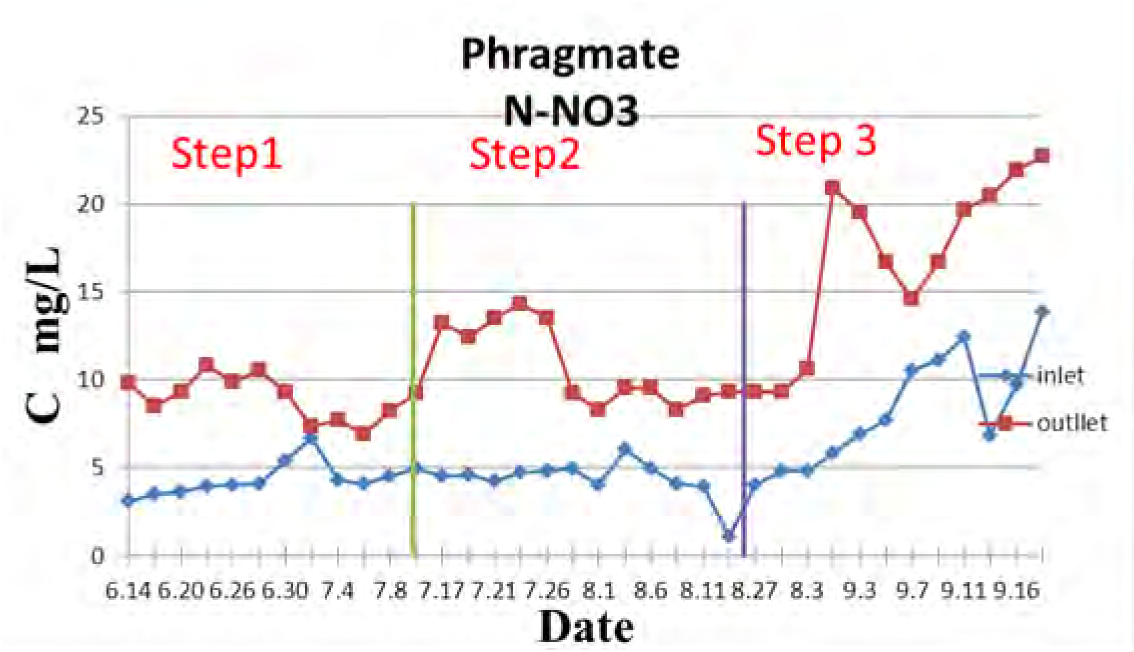

Figure 13. Efficiency removal of N-NO_3 IN Phragmate tanks during three surface loads(8,6,4)m^3/m^2.h and tow circulation ratios (10%,20%) for each load and for one week time for each different load.

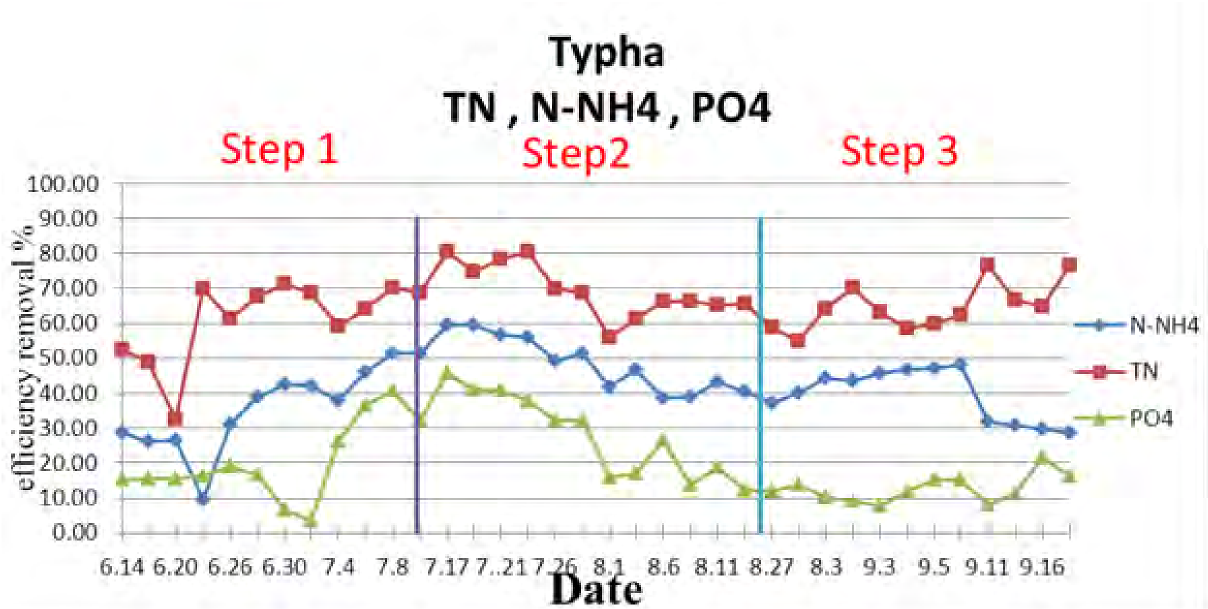

Figure 14. Efficiency removal of TN,N-NH_4,PO_4 IN Typha tanks during three surface loads (8,6,4)m^3/m^2.h and tow circulation ratios (10%,20%) for each load and for one week time for each different load.

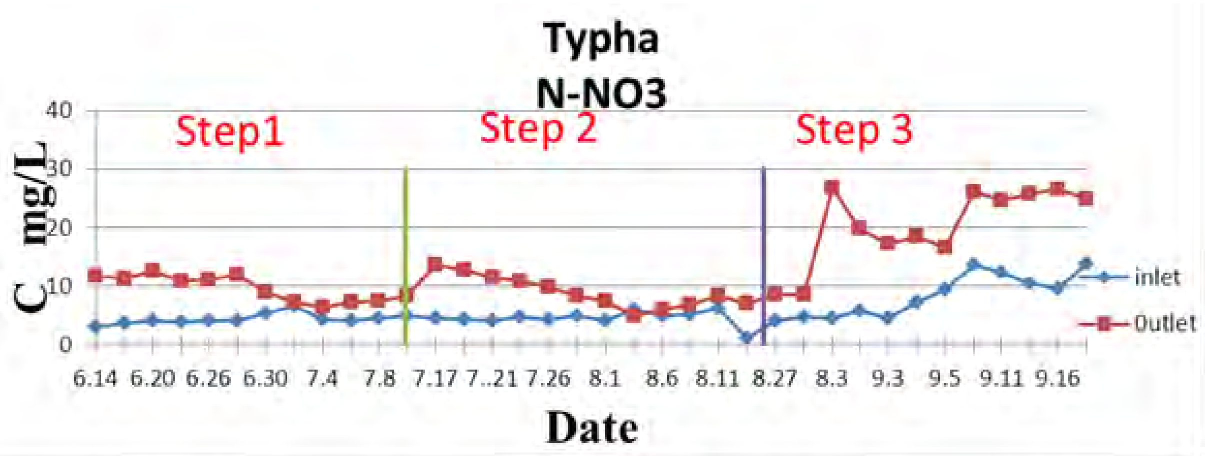

Figure 15. Efficiency removal of N-NO_3 IN Typha tanks during three surface loads (8,6,4)m^3/m^2.h and two circulation ratios (10%, 20%) for each load and for one week time for each different load.

6. Nitrogen removal:

TN removal:

the percentage of efficiency removal has been increased to 80% for the three kinds of emergent plants, during the second step without, recirculation ratio which is a high percentage if compared with other referred studies , and also agreed with the Syrian irrigation standers(2752) [13] [14] .fig (11,13,15)

N-NH4 removal:

the efficiency removal for N-NH4 increased up to 60% by tow emergent plants (Phragmate,Typha) during step 2(6m3/m2 .h) without, recirculation ratio but the efficiency removal decreased during tow recycling periods(10%,20%) in (step2and step 3) to became less than 40% and that is agreed with other referred studies [13] which has provided an explanation for this ,because 30% of N-NH4 will transfer to N-NO2 and N-NO3, and that agreed with the Syrian irrigation standers(2752) [14] . fig (10,12,14)

N-NO3 removal:

according to the last explanation we could also realize that the resulted concentration of N-NO3 has been increased mostly in step 3 during (10% an 20%) recirculation ratio for the three emerged plants, and the best removal result was by Phragmate, Typha, and Botomos respectively, which is agreed with the Syrian irrigation standers(2752). [14]

In addition, this result agreed with referred study [13] which explained that recirculation ratio help to improve the aerobic conditions which could increase the bacteria activation to remove the organic nitrogen in simultaneous with nitrification process, and that will give the reason of reducing the organic nitrogen concentration with increasing nitrate concentration without changing the TN concentration, According to Brix,[38] 1994; IWA, 2000. fig (10,12,14)

PO4 Removal:

we can realize that the efficiency removal for PO4 for those three emerged plants increased during step 2 (6m3/m2.h) without recirculation ratio ,to obtain the removal percentages (45%,32%,20%) in (Typha ,Phragmate,Botomos) tanks respectively, which is indicate that the best phosphorus removal is by Typha tanks 45% , but still less then nitrogen removal percentage because phosphorus bacteria needs anaerobic conditions to remove phosphorus and digest it [15]and also to provide phosphorus to the rhizome as nutrient ,for that , we achieved these anaerobic conditions by Lemna tanks (float plant)as advanced stage in this pilot-scale, and from this we could increase phosphorus removal by extending the detention time in Lemna tanks , as individual stage . we cloud also provide metal elements (oxides of Ca,Fe,Mg..) to resolve phosphorus by adsorption . and obtaining the best phosphorus removal needs pH values (8-9), but in this pilot scale the inlet and outlet values of pH rested between (6-7) in all its tanks [16] [17]. fig (10,12,14)

7. Conclusion

In this research that different surface loads (8,6,4)m3/m2.h are implemented as three steps, with two recirculation ratios (10%,20%) respectively during each those surface loads ,in order to obtain the best efficiency removal of nitrogen and phosphorus from the wastewater as tertiary treatment ,and to provide the Syrian standards of this kind of wastewater treatment .for that we obtained that the surface load (6m3/m2.h) without any circulation ratio obtained a high efficiency removal of all TN and Po4 (80%,45%) respectively in Typha treatment line, then Phragmate provided (less than 80% for TN and 40%for Po4) ,but Botomos line provided less than the last tow kinds of emergent plants for these nutrients removal.

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