Application of Bio-filteration Wastewater Treatment Using Iraqi Gypsum and Phosphate Bio-filters

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***Abstract*-Field experimental work was carried out at the College of Agriculture, University of Anbar, Iraq, for the period from 15/1/2012 to 15/5/2012 using phosphate and gypsum rocks bio-filters to determine the impact on the purification of the sewage by analyzing parameters EC, TDS, Cations (Mg^{+2}, Na^{+}, K^{+}) and anions (HCO_3^- and Cl^-). Two trenches were designed with dimension of (20 m long and 6 m wide) nearby a wastewater tank. Then samples were taken from the inlet and outlet, the water was withdrawn from the bio-filteration system and then repeated the filling and emptying process again. Results showed a significant decrease in the value of EC, TDS Cations (Mg^{+2}, Na^{+}, K^{+}) and anions (HCO_3^- and Cl^-) concentrations for phosphate bio-filters compared to gypsum bio-filters.**

Keywords- Wastewater; Biofilteration; Phosphate; Gypsum; Adsorption; TDS; EC

I. INTRODUCTION

With increasing global population, the gap between the supply and demand for water is widening and is reaching such alarming levels that in some parts of the world it is posing a threat to human existence. The disposal of wastewater is a major problem faced by municipalities, particularly in the case of large metropolitan areas, with limited space for landbased treatment and disposal. On the other hand, wastewater is also a resource that can be applied for productive uses since wastewater contains nutrients that have the potential for use in agriculture, aquaculture, and other activities.

The yearly estimated wastewater in Iraq is 1826*106 m3, 586*106 m3 of which treated by treatment plants [1], so there was a need to develop new types of materials such as phosphate and Gypsum crushed rocks in addition to current methods for the purpose of wastewater treatment. Adsorption is considered one of the most important chemical methods used in wastewater treatment by the adsorbent substance which possesses the ability to withdraw some of the soluble substances and undesirable odors and colors, in addition to being a process of correlation molecules or atoms or ions of a gas or liquid to solid surfaces [2]. The substance that has the adsorption is known as the adsorbat. In this study, two materials Phosphate and Gypsum rocks were used in order to test its efficiency in wastewater treatment for agricultural purposes. Nowadays, bio-filtration system considers one solution proposed for the development and rationalization of consumption of fresh water is the use of treated wastewater as a resource substitute water for agricultural uses, therefore, most Arab countries had expanded in the processes of wastewater treatment for reuse in irrigation where the Arab states use a large quantities of wastewater (treated and untreated) in agriculture.

The main objective of this study is to:

1. Investigate the applicability of field scale system for improving the pollutants removal efficiency by using new types of material such as phosphate and gypsum bio-filters.
2. Improve the wastewater quality after treating and reuse of irrigation.
3. Determine the efficiency of two bio-filtration wastewater treatment systems that serve the small areas.

II. MATERIALS AND METHODS

A. Design and Operation

Experimental work site was selected close to the main source of wastewater, to minimize the cost and other side effects of transporting the wastewater to the bio-filter system for wastewater analysis and nearby the laboratory. A field scale of 20 m by 6 m was selected nearby a wastewater tank located at a part of area of the College of Agriculture, University of Al-Anbar.

B. Gypsum & Phosphate Bio-filters

1) Gypsum Bio-filter:

The gypsum bio-filter with width of bio-filter is 1 m and length of this zone is set to be 10 m. This part was filled with gravel of diameter varying between 20 mm – 50 mm and thickness 50 mm, two plastic pipes were placed along the length of the bio-filter, the length of these pipes 1000 cm with diameter 5 cm, the distance between the effluent pipes was 50 cm linked by joint, layer of the same type of gravel was placed again with a thickness of 10 cm, then placed 4 layers of gypsum crushed rock, the first layer with diameter 15 cm, the second with diameter 10 cm, third layer with diameter of 5 cm and the fourth

layer which was located on the surface with diameter varying between 2-3 cm. Gypsum rock was analyzed using the sedimentation method with an acetone solution [3] as shown in Table 1.

TABLE 1 CHEMICAL ANALYSIS FOR THE GYPSUM ROCK USED IN BIO-FILTRATION SYSTEM

Comp.	SiO_2	Fe_2O_3	Al_2O_3	$CaSO_4$	$CaCO_3$
%	0.25	0.05	0.42	57.24	3.28

2) The Phosphate Bio-filter:

The phosphate crushed rock is the basis material zone. The width of bio-filter is 1 m, then length of this zone is set to be 10 m. This part was filled with gravel of diameter varied between 20mm and 50mm and thickness 50 mm. Two plastic PVC pipes were placed along the length of the bio-filter, the length of these pipes 10 m and diameter 5 cm. The distance between the PVC plastic pipes was 50 cm linked by joint. A layer of the same type of gravel was placed again with a thickness of 10 cm, and a layer of sand with a thickness 10 cm has been placed. The purpose of this layer was to prevent the passage of phosphate rock (crushed) on the PVC plastic pipes. A layer of phosphate crushed rock was placed at the surface of bio-filter, a thickness of this layer 40 cm. Phosphate crushed rock was analyzed as shown in Table 2 to identify the chemical and physical properties.

TABLE 2 PHYSICAL AND CHEMICAL PROPERTIES FOR THE PHOSPHATE ROCK USED IN BIO-FILTRATION SYSTEM

Physical specifications		Chemical specifications			
Rock properties		Compound	Weighted average%	Compound	Weighted average%
Rock type	Apatite	P_2O_5	21.47	F	2.88
Chemical Formula	$Ca_5(PO_4)_3F$	CaO	50.98	Cl	0.125
Bank density	1.84 ton/m^3	MgO	0.60	Zn	150 ppm
Exported density	1.424 ton/m^3	CO_2	17.26	Sr	800 ppm
B.P.L (Bone phospatic limestone)	46%	SiO_2	2.24	V	120 ppm
P2O5	21.04%	R_2O_3	0.67	U	72 ppm
Moisture%	Dry	SO_3	1.70	Y	80 ppm

C. Wastewater Supply

The wastewater source within the underground reservoir (6.5×3.5×4) m was used to supply one parallel rectangle tank with dimension (2×1×1) m by using a submerged pump. The network consists of a plastic pipe transporting the wastewater from the supply tank to two hoses, with the same diameter, each provided by a flowmeter to control the discharge influents to the bio-filter. The tank was placed on a hill rising three meters, and was provided with float and sensor. A cock was used to collect the samples of water from the outlet of the bio-filters. Clean labeled glass bottles were used to save the samples. A cooling plastic container was used to save the samples bottles when transported to the laboratory, the container contains sufficient ice to keep the samples below 4 ℃ to retard the bacterial processes within the samples.

D. Wastewater Quality Analysis

The physical, chemical, and biological wastewater quality parameters were analyzed. The samples were analyzed at Central Laboratory, College of Agriculture at the University of Anbar (CLCA).

Ions and cations were estimated, the amount of calcium Ca^{+2} and magnesium Mg^{+2} were estimated with titration process with Versanet (EDTA) according to [3] while sodium (Na^+) and potassium (k^+) were estimated using Flamephotometer device according to [3]. Chloride (Cl^-) was estimated by titration process with nitrate of Silver [3]. Bicarbonate (HCO^-_3) was estimated by titration process with sulfuric acid [3].

III. RESULTS AND DISCUSSION

A. Physiochemical Parameters

1) Electrical Conductivity (EC):

The electrical conductivity of water estimates the total amount of salts dissolved in water TDS, which stands for total dissolved solids. TDS is measured in ppm (part per million) or in mg/l.

From Fig. 1 it was noted that the significant removal of EC ($P \leq 0.05$) in effluent was compared to its average values in the influent. Average EC value at first period was 3.07 ds/m in influent while in biofilters effluent was 2.87 ds/m and 2.58 ds/m respectively, and average EC value was decreased about 6.5% in gypsum biofilter and 16% in phosphate biofilter in the effluent.

The significant removal of EC ($P \leq 0.05$) in effluent was compared to its average values in the influent. Average EC value at second period was 3.06 ds/m in the influent while in biofilters effluent was 2.88 ds/m and 2.54 ds/m respectively, and average EC value was decreased about 5.88% in gypsum biofilter and 20.4 % in phosphate biofilter in the effluent.

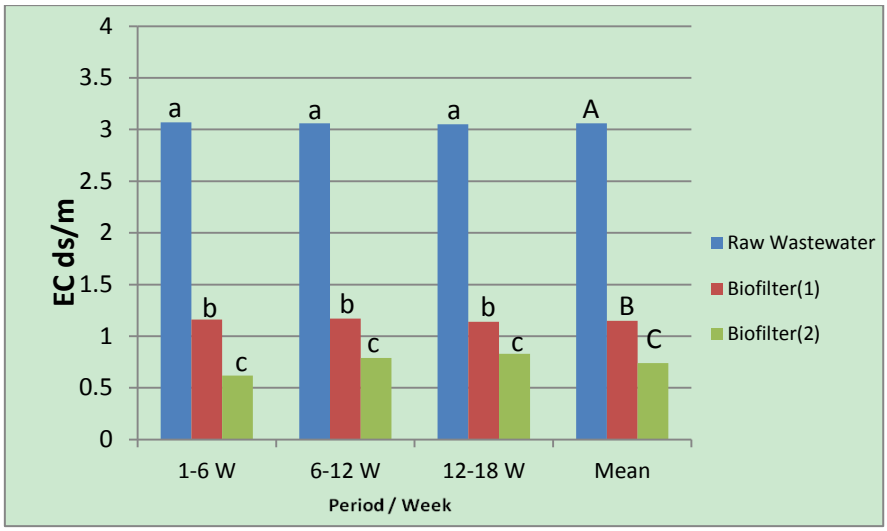

Fig. 1 Effect of biofilter (1) (Gypsum biofilter) and biofilter (2) (Phosphate biofilter) in the treatment of raw wastewater in the value of EC ds/m

The significant removal of EC ($P \leq 0.05$) in effluent was compared to its average values in the influent. Average EC value at third period was 3.05 ds/m in the influent concentration while in biofilters effluent was 2.81 ds/m, 3.04 ds/m respectively, and average EC value was decreased about 7.86% in gypsum biofilter and 0.37% in phosphate biofilter in the effluent. The study indicated the low efficiency of the filter in the third period perhaps due to the aging of the filter.

The significant decreasing of EC ($P \leq 0.05$) in effluent was compared to its average values in the influent. Mean value of EC during the study period was 3.06 ds/m in influent while in biofilters effluent was 4.02 ds/m and 2.64 ds/m respectively, average EC value after treated was decreased about 13% in gypsum biofilter and 13.7% in phosphate biofilter as compared to its average value for effluent.

The decreasing of EC value can be observed compared to untreated water and this is due to the adsorption section of the cation or deposited, leading to a reduction in the value of the treated water (as reduced as the amount of ions decrease the value of the EC) as described in the following equation:

$$\text{meq/L} = \text{EC} \times 10$$

The sum of anions equals the sum of cations and meq/l equals the sum of anions or the sum of cations [4].

2) Total Dissolved Solid (TDS):

The Total Dissolved Solid represents the soluble salts which combine the correlated ions and cations. In Fig. 2 the significant removal of TDS ($P \leq 0.05$) in effluent was observed as compared to its average values in the influent. Average TDS value at first period was 1968.22 mg/l in influent while in effluent (gypsum, phosphate) biofilter was 1869.86 mg/l, 1650.02 mg/l respectively, average TDS value was decreased about 5% which was observed in gypsum biofilter and 16.1% in phosphate biofilter in effluent.

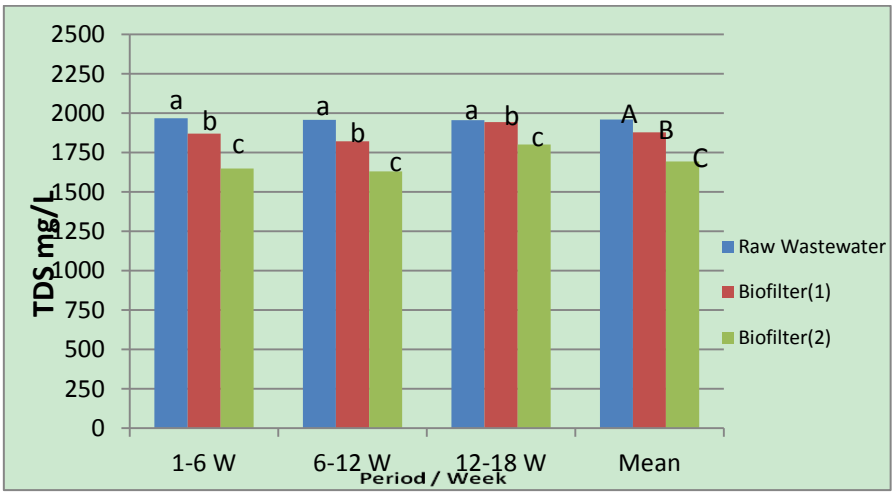

Fig. 2 Effect of biofilter (1) (Gypsum biofilter) and biofilter (2) (Phosphate biofilter) in the treatment of raw wastewater in the value of TDS mg/L

The significant removal of TDS ($P \leq 0.05$) in effluent was compared to its average values in the influent. Average TDS value at

second period was 1958.29 mg/l in the influent while in effluent (gypsum, phosphate) biofilter was 1822.28 mg/l 1630.90 mg/l respectively; average TDS value was decreased about 7% which was observed in gypsum biofilter and 16.7% in phosphate biofilter in effluent.

The significant removal of TDS ($P \leq 0.05$) in effluent was compared to its average values in the influent. Average TDS value at third period was 1955.58 mg/l in the influent while in biofilters effluent was 1943.87 mg/l 1801.60 mg/l respectively. Average TDS value was decreased about 0.6% in gypsum biofilter and 7.87% in phosphate biofilter effluent.

The significant removal of TDS ($P \leq 0.05$) in effluent was compared to its average values in the influent. Mean value of TDS during the study period was 1960.41mg/l in the influent while in biofilters effluent was 1879.19mg/l and 1694.77mg/l respectively. Average TDS value was decreased about 4 % which was observed in gypsum biofilter and 13.5% in phosphate biofilter effluent. From the results, it was noted that the difference is clear in the value of phosphate crushed rock which was the best treatments experience.

There is no explanation to the behavior of the TDS variation within the two biofilteration systems. There may be other factors that should be taken such as salts within the raw material of the biofilteration [5].

B. Major Cation Concentrations

1) Magnesium Concentration (Mg^{+2}):

Fig. 3 shows that the magnesium is usually removed from water, because of the role that magnesium plays in water hardness. The significant removal of Mg^{+2} ($P \leq 0.05$) in effluent was compared to its average values in the influent. Average Mg^{+2} value at first period was 5.11 mg/l in influent while in biofilters effluent was 1.96 mg/l and 0.70 mg/l respectively, average Mg^{+2} value was decreased about 61.6% in gypsum biofilter and 86.3% in phosphate biofilter effluent.

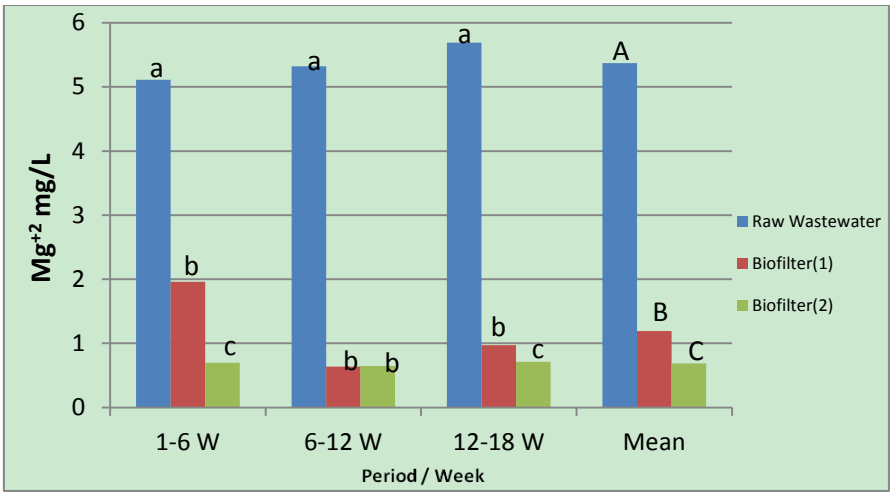

Fig. 3 Effect of biofilter (1) (Gypsum biofilter) and biofilter (2) (Phosphate biofilter) in the treatment of raw wastewater in the value of Mg^{+2} mg/L

The significant removal of Mg^{+2} ($P \leq 0.05$) in effluent was compared to its average values in the influent. Average Mg^{+2} value at second period was 5.32 mg/l in influent while in biofilters effluent was 0.64 mg/l and 0.65 mg/l respectively, average Mg^{+2} value was decreased about 88% in gypsum biofilter and 87.8% in phosphate biofilter in effluent.

The significant removal of Mg^{+2} ($P \leq 0.05$) in effluent was compared to its average values in the influent. Average Mg^{+2} value at third period was 5.69 mg/l in influent while in biofilters effluent was 0.97 mg/l and 0.71 mg/l respectively, average Mg^{+2} value was decreased about 83% in gypsum biofilter and 87.5% in phosphate biofilter in effluent. The low efficiency of the filter in the third period was perhaps due to the aging of the filter.

Mean value of Mg^{+2} during the study period was 5.37 mg/l in influent while in biofilters effluent was 1.19 mg/l and 0.69 mg/l respectively, average Mg^{+2} value was decreased about 77.8% in gypsum biofilter and 87.15% in phosphate biofilter in effluent as compared to its average value for effluent, it was observed decreasing the value of Mg^{+2} in effluent water compared with influent may be due to adsorption and precipitation process [6]. It was noted that the difference was clear in the value of phosphate crushed rock which was the best treatments experience because of the increased surface area (powder).

2) Sodium Concentration (Na^{+}):

Fig. 4 shows the significant removal of Na^{+} concentration ($P \leq 0.05$) in effluent as compared to its average values in the influent. Average Na^{+} values at first period was 11.52 mg/l in influent while in biofilters effluent was 5.78 mg/l and 5.56 mg/l respectively, average Na^{+} value was decreased about 50% in gypsum biofilter and 51.7% in phosphate biofilter in effluent.

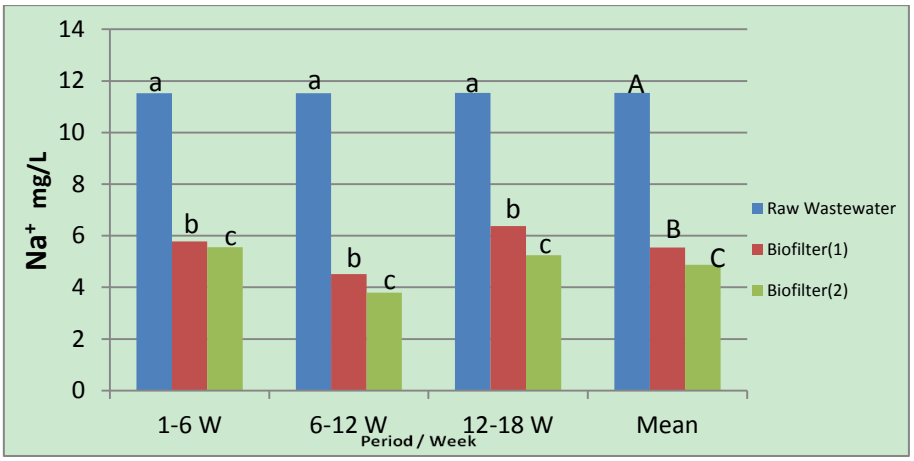

Fig. 4 Effect of biofilter (1) (Gypsum biofilter) and biofilter (2) (Phosphate biofilter) in the treatment ofraw wastewater in the value of Na^+ mg/L

The significant removal of Na+ ($P \leq 0.05$) in the effluent was compared to its average values in the influent. Average Na^+ value at the second period was 11.52 mg/l in influent while in biofilters effluent was 4.52 mg/l and 3.8 mg/l respectively, average Na^+ value was decreased about 60.7% in gypsum biofilter and 67% in the phosphate biofilter effluent.

The significant removal of Na^+ ($P \leq 0.05$) in effluent was compared to its average values in the influent. Average Na^+ value at third period was 11.54 mg/l in influent while in biofilters effluent was 6.37 mg/l and 5.25 mg/l respectively, average Na^+ value was decreased about 44.8% in gypsum biofilter and 54.5% in phosphate biofilter in effluent, It was observed that the low efficiency of the filter in the third period was perhaps due to the aging of the filter.

The significant removal of Na^+ ($P \leq 0.05$) in effluent as compared to its average values in the influent. Mean value of Na^+ during the study period was 11.53 mg/l in influent while in biofilters effluent was 5.54 mg/l and 4.87 mg/l, respectively, average Na^+ value was decreased about 52% in gypsum biofilter and 57.76 % in phosphate biofilter in effluent as compared to its average value for effluent.

It was noted that the decreasing in the value of Na^+ in the effluent water compared with the influent may be due to adsorption process [6]. It was observed that the difference was clear in the value of phosphate crushed rock which was the best treatments experience because of the increased surface area (powder).

3) Potassium Concentration (K^+):

Fig. 5 shows the significant removal of K^+ ($P \leq 0.05$) in effluent as compared to its average values in the influent. Average K^+ value at first period was 0.41 mg/l in influent while in biofilters effluent was 0.34 mg/l and 0.26 mg/l respectively, and 17% decreases in average K^+ value was observed in gypsum biofilter and 36.58% in phosphate biofilter in effluent.

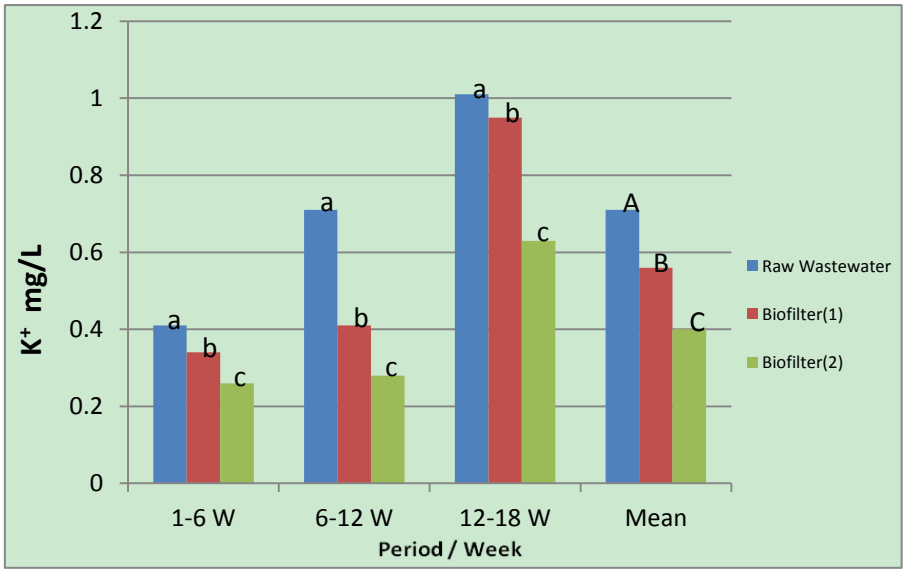

Fig. 5 Effect of biofilter (1) (Gypsum biofilter) and biofilter (2) (Phosphate biofilter) in the treatment of raw wastewater in the value of K^+ mg/L

The significant removal of K^+ ($P \leq 0.05$) in effluent as compared to its average values in the influent. Average K^+ value at second period was 0.71 mg/l in influent while in biofilters effluent was 0.41mg/l and 0.28 mg/l respectively, average K+ value

after treated was decreased about 42.2% in gypsum biofilter and 60.5% in phosphate biofilter as compared to its average values in effluent.

The significant removal of K^+ ($P \leq 0.05$) in effluent was compared to its average values in the influent. Average K^+ value at third period was 1.01mg/l in influent while in biofilters effluent was 0.95mg/l and 0.63 mg/l respectively, and average K^+ value was decreased about 6% in gypsum biofilter and 37.6 % in phosphate biofilter in effluent. It was noted the low efficiency of the filter in the third period was perhaps due to the aging of the biofilter.

The significant removal of K^+ ($P \leq 0.05$) in effluent was compared to its average values in the influent. Mean value of K^+ concentration during the study period was 0.71 mg/l in influent while in biofilters effluent was 0.56 mg/l and 0.40 mg/l respectively, and average K^+ value was decreased about 21.1% in gypsum biofilter and 43.6% in phosphate biofilter in effluent as compared to its average value for effluent. It was noted the decreasing the value of K^+ in effluent water compared with influent may be due to positive adsorption process [7]. It was noted that the phosphate crushed rock was the best treatments experience because of the increased surface area (powder).

C. Major Anions

1) Bicarbonate Concentration (HCO_3^-):

Fig. 6 shows the significant removal of HCO_3^- ($P \leq 0.05$) in effluent as compared to its average values in the influent. Average HCO_3^- value at first period was 9.8 mg/l in the influent while in effluent (gypsum, phosphate) biofilter 4.18, 3.44 mg/l respectively, average HCO_3^- value was decreased about 57.3% in gypsum biofilter and 64.9% in the phosphate biofilter effluent.

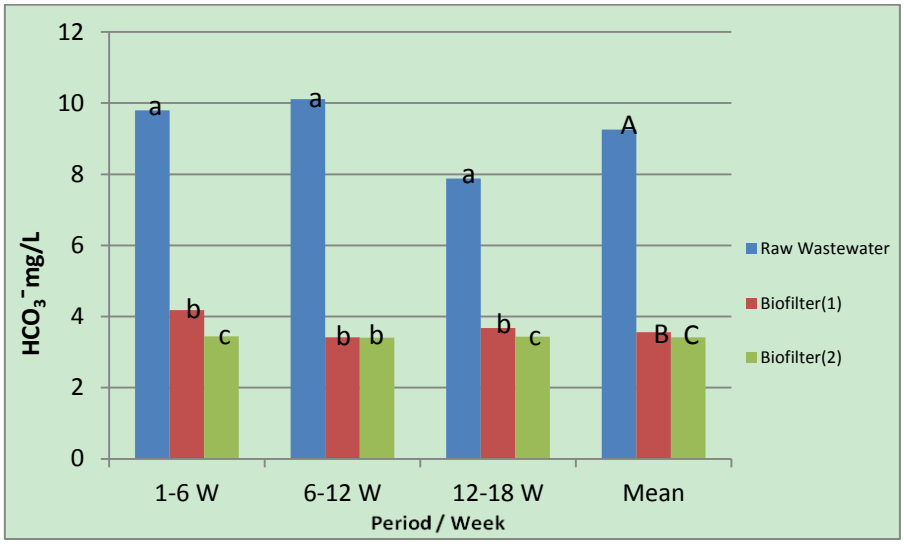

Fig. 6 Effect of biofilter (1) (Gypsum biofilter) and biofilter (2) (Phosphate biofilter) in the treatment of raw wastewater in the value of HCO_3^-mg/L

The significant removal of HCO_3^- ($P \leq 0.05$) in effluent was compared to its average values in the influent. Average HCO_3^- value at second period was 10.11 mg/l in influent while in biofilters effluent was 3.42mg/l and 3.41 mg/l respectively, and average HCO_3^- value was decreased about 66.1% in gypsum biofilter and 66.27% in phosphate biofilter in effluent.

The significant removal of HCO_3^- ($P \leq 0.05$) in effluent was compared to its average values in the influent. Average HCO_3^- value at third period was 7.88 mg/l in influent while in biofilters effluent was 3.68 mg/l and 3.43 mg/l respectively, and average HCO_3^- value was decreased about 53.3% in gypsum biofilter and 56.5% in phosphate biofilter in effluent. It was noted the low efficiency of the filter in the third period perhaps due to the aging of the biofilter.

The significant removal of HCO_3^- ($P \leq 0.05$) in effluent was compared to its average values in the influent. Mean value of HCO_3^- during the study period was 9.26 mg/l in influent while in biofilters effluent was 3.56 mg/l and 3.42 mg/l respectively, and average HCO_3^- value was decreased about 61.5% in gypsum biofilter and 63% in phosphate biofilter in effluent as compared to its average value for effluent. It was noted decreasing in the value of HCO_3^- in the effluent water compared with influent may be due to negative adsorption process and precipitation [8].

2) Chloride Concentration (Cl^-):

Fig. 7 shows the significant removal of CL^- ($P \leq 0.05$) in effluent as compared to its average values in the influent. Average Cl^- value at first period was 12.51 mg/l in influent while in effluent (gypsum, phosphate) biofilter 10.05, 1.2 mg/l respectively. Average Cl^-value was decreased about 19.66% in gypsum biofilter and 90.4 % in phosphate biofilter in effluent.

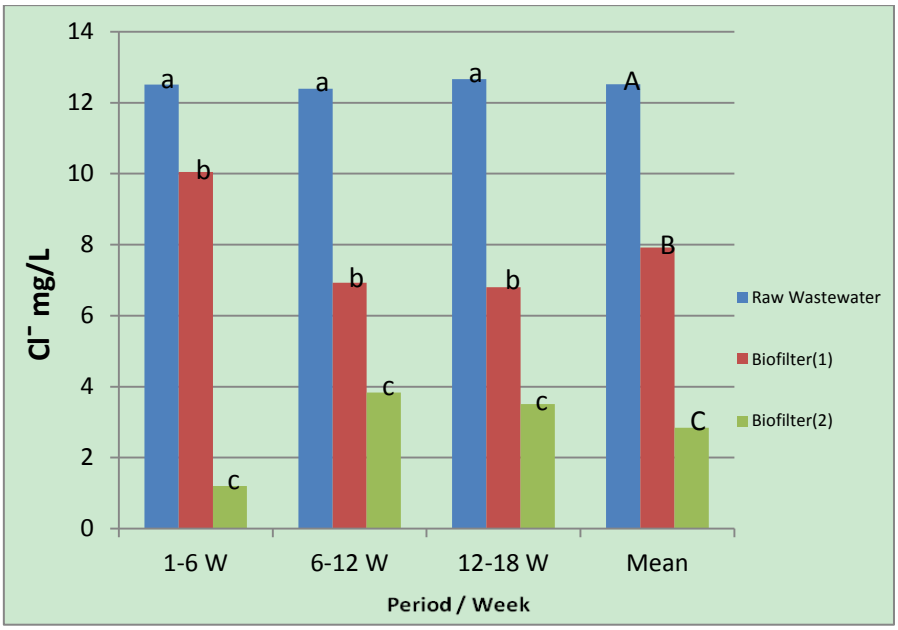

Fig. 7 Effect of biofilter (1) (Gypsum biofilter) and biofilter (2) (Phosphate biofilter) in the treatment of raw wastewater in the value of Cl^- mg/L

The significant removal of Cl^- ($P \leq 0.05$) in effluent was compared to its average values in the influent. Average Cl^- value at second period was 12.39 mg/l in influent while in biofilters effluent was 6.93 mg/l and 3.83 mg/l respectively, average Cl^- value was decreased about 44 % in gypsum biofilter and 69% in phosphate biofilter in effluent.

The significant removal of Cl^- ($P \leq 0.05$) in effluent was compared to its average values in the influent. Average Cl^- value at third period was 12.66 mg/l in influent while in biofilters effluent was 6.8 mg/l and 3.51 mg/l respectively. Average Cl^- value was decreased about 46.3% in gypsum biofilter and 72.3% in phosphate biofilter in effluent. It was noted the low efficiency of the filter in the third period perhaps due to the aging of the filter.

The significant removal of Cl^- ($P \leq 0.05$) in effluent was compared to its average values in the influent. Mean value of Cl^- during the study period was 12.52 mg/l in influent while in biofilters effluent was 7.92 mg/l and 2.84 mg/l respectively, and average Cl^- value was decreased about 36.7% in gypsum biofilter and 77.3% in phosphate biofilter in effluent as compared to its average value for effluent. It was observed heavy decrease in the value of chloride in the beginning of effluent water compared with influent water result to negative adsorption process while later we observed gradual increase may be due the exposition to the process of precipitation and adsorption in the biofilter especially in gypsum biofilter. It was noted that the difference was clear in the value of phosphate crushed rock which was the best treatments experience because the Phosphate has more abilities of adsorption [9].

IV. CONCLUSIONS

The results show that biofiltration system was significant for decreasing (Mg, Na, k, HCO_3 & Cl) concentrations from (5.37), (11.53), (0.71), (9.26) and (12.52) to (1.19) mg/l, (5.54) mg/l, (0.56) mg/l (25.14)mg/l and (7.92) mg/l respectively in gypsum biofilter, and (Mg, Na, k, HCO_3 & Cl) concentrations from (0.69) mg/l, (4.87) mg/l, (0.4) mg/l and (3.42) mg/l and (2.84) mg/l respectively in phosphate biofilter. The last period operation of bio-filtration system was less efficient for removal of cations, anions, EC and TDS concentration may be attributed to the aging of bio-filters, clogged pores and temperatures increasing. It was noting that the Phosphate bio-filter was better for decreasing of cations, anions, EC and TDS concentration than the gypsum bio-filter in all the experimental tests.

V. RECOMMENDATIONS

The recommendations were suggested for future studies that many selective media in Iraq with low density, high internal porosity and based chemical composition must be tested to investigate the hydraulic behavior of bio-filtration wastewater systems such as Dolomite. Through this study, we recommend using the rock phosphate as a powder due to its ability of higher adsorption because of the surface area increasing.

Since the treatment processes in bio-filtration system are influenced by many parameters, the following should be evaluated in designing the system: location, wastewater characteristics, treatment system size, detention time, and bio-filters size and uniformity. Gypsum and Phosphate bio-filters are recommended to be used in small communities in rural area for treating wastewater.

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