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Developing Sustainable Wastewater Treatment Systems Using Biofiltration Process

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ABSTRACT

Treating wastewater is a crucial process to save the environment and provide freshwater conservation tools. This study aimed to develop a sustainable wastewater treatment process based on the biofiltration process. This study experiments employed two of the available local raw materials as filter media for biofiltration to treat the raw wastewater. The Dolomite ($CaCO_3$, $MgCO_3$), and Anhydrite crushed rocks ($CaSO_4$) were selected. The study was performed by constructing two pilot-scale biofiltration systems for 18 operation weeks. A group of wastewater quality parameters of the influent and effluent were tested at different periods of operation such as BOD_5, COD, pH, TDS, EC, cations, and anions: Mg^{+2}, Ca^{+2}, K^+, Na^+, HCO_3^-, Cl^-, NO^{-3}, and sodium absorption ratio (SAR). The results showed that both biofilters had high removal rates for BOD_5 and COD a low fluctuation based on period time. It is worth mentioning that the highest BOD_5 and COD removals were achieved in the first 6 weeks using the Dolomite filter reaching 95% and 96% respectively. Moreover, the following treatment using Dolomite showed high-efficiency removals for anions and cations such as Mg^{+2} (87.15%), Na^+ (57.76%), K^+ (43.6%), Cl^- (77.3%), NO_3^- (92%) and HCO_3^- (63%). Also, the results indicated that the treated wastewater can be reused for irrigation purposes based on SAR which was 1.73. Meanwhile, the Anhydrite biofilter showed a low efficiency of anions and cations removals compared to Dolomite. For instance, the removal efficiency for Mg^{+2}, Na^+, K^+, Cl-, NO_3^-, HCO_3^- were 77.8%, 52%, and 21.1% 36.7 %, 52 % and 61.5%, respectively and SAR was 2.1 epm. In conclusion, the proposed biofiltration systems showed high removal rates for various pollutants from wastewater with some superiority for Dolomite media.

1. INTRODUCTION

Water is the secret of all forms of life, but water resources are becoming increasingly either polluted or scarce in many areas around the world. The increase in population growth, accompanied by intense urbanization and industrial activities worsens water problems and results in massive quantities of wastewater [1]. Water pollution has led to a substantial effect on sustainability, humanitarian development, and agricultural production that requires sufficient quantities of water to achieve food security [2, 3]. Therefore, proper and sustainable treatment of wastewater represents a real opportunity to provide another environmental remedy for polluted water. This will help to decrease the water stresses and lack of freshwater resources in some areas such as Iraq. The lack of fresh water is a result of the fluctuation of flow rates and pollution in surface water resources [4, 5]. Therefore, there is a need to exploit all available sources of water such as recycling wastewater to meet the increasing in water demand. In Iraq, many areas suffer from the lack of treatment plants for wastewater, consequently magnifying the water pollution in the watershed due to the direct disposal of watersheds (Tigris and Euphrates rivers) [6]. Untreated wastewater negatively affects water quality and human health. Therefore, the wastewater must be treated through a series of physical and chemical processes before being released into the local water system (or disposed of from the source) to save the environment and promote a healthy life [7].

Many techniques have been experimented with as applicable routes to alleviate wastewater problems. However, most of these techniques are highly energy-consuming and need sizable maintenance and operation [8]. Biofiltration technique is a proposed solution to treat wastewater that can be a viable and rationalized tool to provide extra quantities of fresh water via treated wastewater to substitute some water quantities for drinking and agricultural uses. Biofiltration is an adorable and advantageous technique to control pollution that involves the removal of contaminants from wastewater. The biofiltration process can remove taste, and odorous substances, disinfection products, reduce organic carbon (assimilable and total), and/or set up biologically stable waste [9]. Biofiltration offers an efficient and eco-friendly process utilizing microorganisms such as bacteria and microalgae to effectively break down any pollutants in the wastewater [10]. Biofiltration system in a wastewater treatment plant involves a low initial investment, no exterior chemicals or fuel necessities, low energy consumption, low maintenance costs, treating multiple contaminants in the same period, as well as public approval as a "natural" process [11, 12]. The biofiltration process can be separated into three major phases: media adsorption, growth and development of microorganisms, and detaching or removing the microorganisms [13]. Different categories of chemical pollutants can be eliminated via biotransformation and sorption in this process. Based on the principle of the biofiltration process, selecting the appropriate filter media where the organism can persist is a very important parameter in designing an appropriate biofilter. The media should have a considerable surface area with high porosity and uniform pore size distribution so that more microorganisms can adsorb onto it [14]. Nevertheless, there is a concern about the filter materials that should be affordable and applicable in terms the technical design, providing high porosity and specific surfaces with low flow resistance. So, there is a need to select the proper types of filter media materials for wastewater treatment using the biofiltration process. A wide array of materials such as Dolomite and Anhydrite menials showed an ability to adsorb some contaminates such as heavy metals during chemical methods used for wastewater treatment [15, 16]. These materials can remove some of the soluble materials and unwelcome aromas and colors through the adsorption process. As a result, in this context, it is possible to explore Dolomite and Anhydrite to accomplish the best wastewater treatment biofiltration technique in a country such as Iraq. These materials are available at low cost in this country. Based on our knowledge there is no study has experimented the Dolomite and Anhydrite crushed rock as biofilter media. Therefore, this study aims to test the efficiency of Dolomite and Anhydrite crushed rock as biofilter media to remove contaminates from wastewater treatment. Moreover, this study investigates the applicability of pilot-scale biofiltration systems using Anhydrite crushed rocks ($CaSO_4$) and Dolomite ($CaCO_3$, $MgCO_3$) for wastewater remedy systems that aid small areas and make this effluent proper for agricultural purposes. The paper's layout is designed based on the standard IMRAD structure (Introduction, Materials and Methods, Results and Disscusstion, and Conclusion).

2. MATERIALS AND METHODS

2.1 Constructing the biofilters

A pilot scale site of 15 m in length and 6 m in width was selected near the main wastewater effluent of the University of Anbar. Two experimental horizontal subsurface biofilters were constructed simulating the sand filters. The first step of constructing the bio-filters included excavating two parallel trenches. The dimensions of each trench were 7 m in length, 2 m in width, and 1 m in depth, with slope sides (45°) and horizontal bottom. They are surrounded by dikes of 10 cm to prevent any incoming surface runoff. A sideway of 1 m was around and between the trenches made to facilitate the periodic cleaning. A plastic cover of polyethylene material (industrial nylon) was used for lining these trenches to prevent the leachate into the soil. The source of raw wastewater influent was supplied from underground storage wastewater (6.5 × 3.5 × 4) m. The wastewater was lifted to a container with dimensions 2 × 1 × 1 m using an underwater pump. The submerged pump was capped by an iron cage with dimensions 60 × 30 × 55 cm. The tank was elevated 3 meters above the ground and equipped with float and sensor. An electrical, automatic switch float was connected sequentially with the pump to keep a continuously and constantly discharging supply during the experiment time. Two outlet hoses with a diameter of 5 cm were branched from the tank and served as influent pipes for the trenches. A flowmeter was installed to control the discharge influents to the biofilters during the performance the experiment setup.

2.2 Biofilter media bed

The biofilter comprised five layers in the filter bed. The materials of media were spread along the length and width of the biofilter (7 m × 2 m). The first layer (the base layer) was filled with 15 cm of graded gravel (ø = 20-50 mm). Then, under the drain system, two plastic pipes were installed along the filter above the base layers to collect filtered water evenly from the filter. These pipes have an inner diameter of 5 cm, and the distance between them was 50 cm, and connected by junction were used. By the same token as the base layer, the extra layer of gravel was added above the drain system. The third layer included 10 cm of sand. This layer was added above the second layer of gravel to protect the fourth layer (the basic filtration layer) and prevent clogging of the drain pipes. The basic filtration layer comprised 40 cm of crushed Anhydrite rocks in biofilter 1. The chemical characteristic of crushed Anhydrite rocks is illustrated in Table 1. This layer in biofilter 2 was filled out with 40 cm of crushed Dolomite rocks that were composed of chemicals. Dolomite rocks that were mainly composed of chemicals. Finally, the fifth layer was added on the surface of the filter including 5 cm of gravel (ø = 20-50 mm) to protect against weather conditions such as heavy wind or rain.

Table 1. Properties of the anhydrite rock used in the biofiltration system

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

2.3 Analytical procedure

Firstly, the wastewater was left for 3 days to the interaction between the basic material of the media of the filter (Anhydrite or Dolomite). Then the samples were taken from the outlet and the director that had been done and emptied the filter, then repeated. During operation, the wastewater level within the filter was 5 cm below the media surface to minimize evaporation from the free surface of the wastewater. The wastewater was discharged by perforated plastic pipes placed along the filter, Anhydrite was estimated utilizing the sedimentation procedure with acetone [17]. A sample collector was used to collect the wastewater from the outlet of the biofilters and to preserve these samples in clean labeled glass bottles [18]. The field measurement and sample testing extended for four months after setting up and operating the two biofiltration systems at different flow rates and different temperatures as shown in Table 2. This period is essential to ensure that bacteria growth and the chemical reactions are properly accrued. The samples were tested by laboratories of the Directorate of Environment Anbar. Meanwhile, temperature (°C), and pH were measured in the field. The initial characteristic of the domestic wastewater was detected before wastewater entered the biofiltration system. A flow meter was used to measure the wastewater influent and effluent of the biofilters by using a graded volumetric cylinder and stopwatch. The pH measurements were made with the help of a portable pH meter (model PC 300 series), meanwhile, total suspended solids as the known quantity of well-mixed samples, were filtered via a weighed standard glass fiber filter. The residue retained on the filter was dried to a steady weight at 103-105℃. The gain in the filter weight represented all the suspended solids. Quantity in milligrams per liter was calculated [19].

Total dissolved solids as the known quantity of well-mixed samples were filtered through a standard glass fiber filter, the filtrate was evaporated to dryness in a weighed dish and dried to constant weight at 180℃. The increase in dish weight was the total dissolved solids in that particular volume of the sample. Milligram per liter of total dissolved solids was calculated [20].

The electrical conductivity (EC) was measured using a potable EC devise type HANNA-HI2880. The biofilters by using a graded volumetric cylinder and stopwatch. Dissolved Oxygen Meter (HANNA-HI9146) within its properties. Ions and cations were calculated; Mg^{+2} and Ca^{+2} were titrated with Versanet (EDTA); Na^{+} and K^{+} were calculated using a flame photometer [21]. Chloride (Cl^{-}) was with titrated silver nitrate [21]. Sulfate (SO_4^{-2}) was estimated via turbidity procedure with a spectrophotometer at 470 nm using $BaCl_2$ [20]; nitrate (NO^{-3}) was estimated by spectrophotometer. Bicarbonates (HCO^{-3}) were titrated with H_2SO_4 [21].

Table 2. Different flow rates, temperatures, and periods of an experiment started in January 2021

Test No.	Periods	Date	Age of Biofilters (days)	Temp. (℃)	Discharge l/min
1	First period	25/01/2021	1	16.5	3
2		01/02/2021	8	15	4
3		08/02/2021	15	15	5
4		15/02/2021	22	14	6
5		22/02/2021	29	16	7
6		29/02/2021	36	17	8
7	Second period	07/03/2021	43	17.5	9
8		14/03/2021	50	19	10
9		21/03/2021	57	20.25	11
10		28/03/2021	64	26.5	12
11		04/04/2021	71	28.75	13
12		11/04/2021	78	30.5	14
13	Third period	18/04/2021	85	32.25	15
14		25/04/2021	92	34	17
15		02/05/2021	99	35.75	18
16		09/05/2021	106	37.5	20
17		16/05/2021	113	39.5	20
18		23/05/2021	120	41.5	20

3. RESULTS AND DISCUSSION

3.1 Organic indicators

Biochemical oxygen demand (BOD) and chemical oxygen demand (COD) are the most commonly used methods to measure the concentration of organic pollution in wastewater. BOD_5 is the biochemical oxidation of organic matter in 5 days. The efficiency of the wastewater treatment process is measured by the ability of this process to remove the organic maters using BOD_5 and COD by comparing their concentrations in influent and effluent. The results showed a decrease in the concentration of BOD_5 and COD on the two biofilters as shown in Tables 3 and 4. The highest removal rates occurred during the first period of operation (P1, 1-6 weeks) in the winter season (January and February) range of Temperature between 1-22℃. Meanwhile, the Dolomite filter showed a slightly higher removal rate of BOD_5 and COD compared to the Anhydrite filter. The BOD_5 and COD removal were 95% and 90%, respectively in biofilter 2 (Dolomite) while The BOD_5 and COD removal were 90% and 89%, respectively in biofilter 1(Anhydrite). After the first period with the increased temperature degrees of weather in the area and pollution loads, the efficiency of both biofilters is decreased. During the second period (P2, 7-12 weeks) of operation, by the same token in P1, biofilter 2 is shown in Table 2. A slightly higher efficiency for BOD_5 removal rates is 84% in biofilter 2 compared to 82% in biofilter 1. On the other hand, both biofilters showed similar COD removal rates (89%). A similar trend of the decrease of efficiency of biofilters in P2 is observed in P3 (13-18 weeks). The BOD_5 removal rates were 75% and 78% for biofilters 1 and 2, respectively. Meanwhile, biofilter 2 showed a distinction in terms of the COD removal rate in P3 with 85% compared to 74% for Bioflter 1. Finally, the overall performance of biofilter 1 and 2 for BOD_5 removal rates were 81% and 84%, respectively, and for BOD_5 removal rates were 84% and 88%, respectively. These results illustrate the possibility of using these types of biofilters for the treatment of wastewater with the superiority of a Dolomite filter.

Table 3. Impact of biofilter 1 (Anhydrite) and biofilter 2 (Dolomite) on BOD_5 (mg/l)

Period Treatment	P_1 1-6 Week	P_2 7-12 Week	P_3 13-18 Week	Mean
Raw Wastewater	270±0.26 a[2]	319±13.96 a	503±20.20 a	364.76±11.47 A[1]
Biofilter 1	26.8±1.03 b	56.5±10.55 b	128.5±7.76 b	70.6±6.04 B
Biofilter 2	22.4±1.53 c	42.33±10.10 c	110.16±21.42 c	58.29±9.29 C

Table 4. Impact of biofilter 1 (Anhydrite) and biofilter 2 (Dolomite) on COD (mg/l)

Period Treatment	P_1 1-6 Week	P_2 7-12 Week	P_3 13-18 Week	Mean
Raw Wastewater	660.4±1.91 a[2]	720.71±13.05 a	806.2±8.17 a	728.97±13.51 A[1]
Biofilter 1	72.10±3.16 b	79.5±6.24 b	207.16±3.44 b	119.5±5.23 B
Biofilter 2	66.7±1.77 c	77.5±5.57 c	117±33.03 c	87.06±19.19 C

[1] Different uppercase letters within a column indicate significant differences at the level of probability ($P \leq 0.05$)
[2] Different lowercase letters (a, b, c..etc.) indicate significant differences at ($P \leq 0.05$)

3.2 Inorganic indicators of water quality

3.2.1 Hydrogen ion concentration (pH)

pH has a great impact on the stability and efficiency of wastewater treatment. Acidic substances in wastewater, such as organic acids, sulfides, or metal ions can result in low pH that may influence the biological treatment process, and increase the toxicity of metals and ammonia. On the other hand, alkaline substances in wastewater, such as ammonia, bicarbonates, or phosphates can lead to high pH that may cause an interference with the chemical treatment process and cause scaling and precipitation of minerals and metals [22]. The variations in wastewater pH were monitored along the time of treatment as shown in Figure 1.

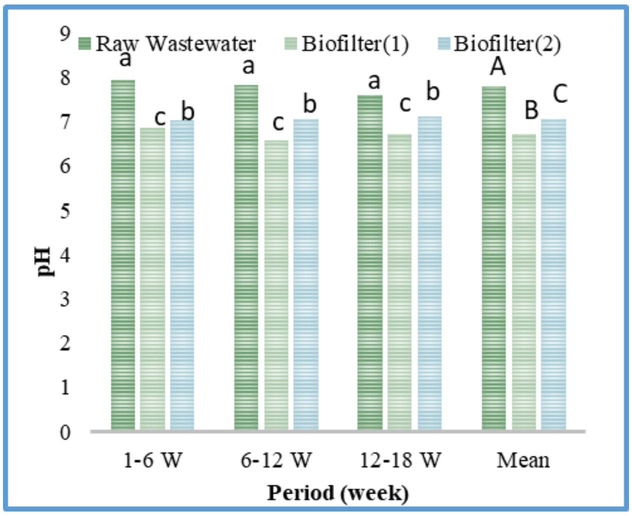

Figure 1. Biofilter effect: Anhydrite and Dolomite on the pH treatment of raw wastewater

The figure shows that the average pH value at the first period was 7.95 in influent then these values significantly decreased in the effluent after the biofilteration treatment. While biofilter effluent was 6.86 and 7.04, the average pH value decreased by 13.7% in Anhydrite and 11.4% in Dolomite effluent. The significant ($P \leq 0.05$) removal of pH was in the effluent in comparison to the influent average. The average pH during the second duration of influent was 7.82; in biofilters, effluent was 6.59 and 7.07 mg/l, respectively. The average pH declined by 15.7%, which was noticed in the Anhydrite and 9.6% in the Dolomite in the effluent. The practical value of pH was in the effluent compared to the influent ($P \leq 0.05$). The average values of pH in the third duration was 7.6 in influent, while in effluent (Anhydrite, Dolomite) was 6.71 and 7.12, respectively. The average pH value dropped by 11.7% in the Anhydrite and 6.3% in the Dolomite in the effluent. The mean pH during the examination duration was 7.79 in the influent which is slightly alkali. On the other hand, the biofilter 1 and 2 effluent pH was near neutral,6.72 and 7.07, respectively. The average pH was decreased by 13.7% in the Anhydrite and 9.24 % in the Dolomite in the effluent. It was documented that there was a difference in the effluent pH compared to the influent. A lower or higher pH value than its allowed limit is highly undesirable from an environmental point of view as it instructs the killing of the microbiological population necessary for biodegradation and pollution control; during the daylight hours, the organisms pull the water CO_2 for photosynthesis and discharge O_2 so that the pH would be increased. This strategy is inverted during the day's dark hours, so diurnal pH and dissolved oxygen variations. From the result, it was reported that the reduction in the pH of the Anhydrite biofilter in comparison to the Dolomite biofilter might be due to the effect of acidic Anhydrite [23]. Average temperature values at both biofilter treatments were not high, therefore pH values did not decrease much after treatment at these treatment plants.

3.2.2 Electrical Conductivity (EC)

One of the important parameters for the qualitative analysis of wastewater systems is the EC). EC has a proportional relationship with the dissolved materials such as minerals, and chemicals in the water that can be referred to as the total dissolved solids (TDS). It is essential to note that the higher the conductivity refers to the higher level of impurities in the water, meanwhile, even slight quantities of pollutants are sufficient to change the wastewater EC usually measured in Siemens (S) per distance (m).

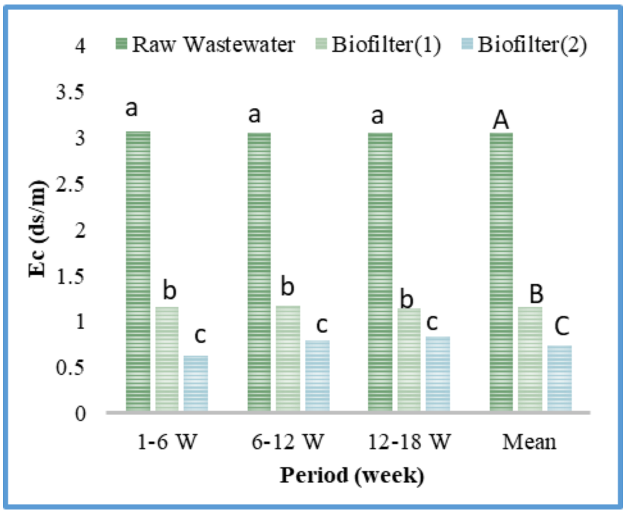

Figure 2. Biofilter effect: 1) Anhydrite and 2) Dolomite on the EC of the raw wastewater treatment

Figure 2 reveals the presence of a significant ($P \leq 0.05$) reduction in EC for the treated wastewater compared to the untreated wastewater. During the first duration, the average EC dropped by 16% and 6.5% of the effluent compared to influent for the Dolomite and Anhydrite filters, respectively. The drop in EC values continued in the second duration. The average value of EC detected at 3.06 ds/m in the raw wastewater. After the treatment the EC of effluent biofilter 1 and 2 recorded 2.54 dS/m and 2.88 dS/m, for the Dolomite and

Anhydrite filters, respectively. The investigation showed a decline in filter efficiency in the third duration especially Dolomite (Biofiltr 2), possibly due to aging. This is because the cation or deposit's adsorption section causes a decrease in the water values that are being addressed (as decreased as the ions reduced the EC value) as depicted in the subsequent equation: meq/L = EC ×10: cations equals the anions; meq/l equals the sum of cations or anions [24].

3.2.3 Total Dissolved Solid (TDS)

As previously mentioned TDS represents the the dissolved materials such as minerals, and chemicals (the soluble salts comprise inorganic salts and organic matter). The high loading of TDS is a common challenge for many wastewater treatment plants TDS is measured in milligrams per liter (mg/l) or parts per million (ppm). In general, TDS ions are not regulated pollutants at accepted limits of the dissolved ions concentration. Therefore it is crucial to decrease their concentrations to meet allowable limits of water quality specifications to avoid the negative effect on aquatic systems and human health. The results showed t a significant ($P \leq 0.05$) reduction in TDS levels in the treated wastewater compared to the raw wastewater as depicted in Figure 3. For instance, during the first duration, the TDS value dropped from 1968.22 mg/l to 1869.86 mg/l and 1650.02 mg/l Anhydrite and Dolomite biofilters, respectively. By the same token, a similar drop in TDS values was observed in subsequent periods. TDS value in the third period was decreased from 1955.58 mg.l-1 in the influent to 1943.87 mg.l-1 (0.6%) and 1801.60 mg.l-1 (7.9%) in the Anhydrite and Dolomite effluents, respectively. Generally, the average reduction along the three periods was significant ($P< 0.05$) by 4 %, as noticed in the Anhydrite, and 13.5% in the Dolomite effluent declaring the superiority of Dolomite as a gainst Anhydrite. However, the salts that may be presence within the biofiltration's raw material could affect the justification of decreasing the mannar of TDS [25].

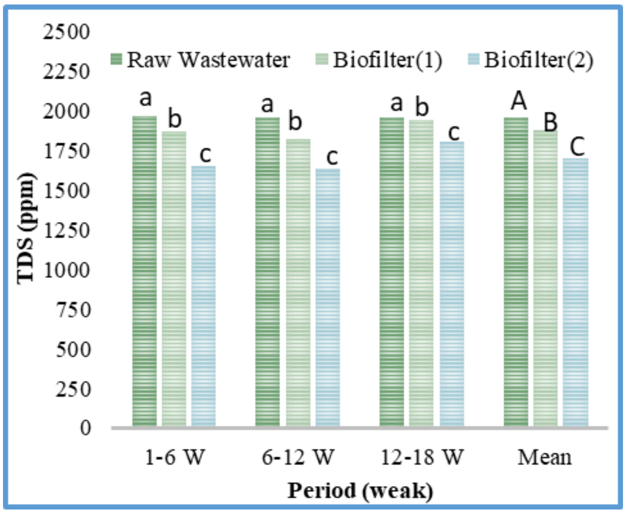

Figure 3. Biofilter effect: 1) Anhydrite and 2) Dolomite on the TDS values of the raw wastewater treatment

3.3 Major cations and anions concentrations

The wastewater treatment aims to remove pollutants from water and reuse water for different purposes. One of the water quality standards is measuring the content of major cations and anions concentrations to ensure water reuse schemes.

3.3.1 Major cations

(1) Calcium concentration (Ca^{+2})

Calcium is the most common cation found in water. The presence of calcium ions in water is vital for human health. However, increasing calcium concentrations over the allowable limits in water quality specifications may cause water hardness [26]. The results showed a unique phenomenon a trend of increasing Ca^{+2} after treatment as shown in Figure 4. For instance, in the first period, the average Ca^{+2} concentration of the effluent was increased to reach 11.81 mg/l and 14.91 mg/l for the Anhydrite and Dolomite biofilters respectively while it was 4.49 mg/l in the influent. A similar observation was recorded during while in the second and third periods of treatment. Generally, along the time of the three periods of investigation, the overall mean of Ca^{+2} concentration was 4.56 mg/l in the raw wastewater and then increased in the treated watewater to 11.09 mg/l and 13.83 mg/l using the Anhydrite and Dolomite biofilters, respectively. As a justification for this trend, the increase in Ca^{+2} in both biofilters might be attributed to the presence of Dolomite and Anhydrite rocks, which are mainly comprised of calcium. It is important to mention that the levels of Ca^{+2} after treatment are lower than those recorded by Iraqi drinking-water standard IQS: 417/2009 Ca (50 ppm) [7] or WHO standard [27].

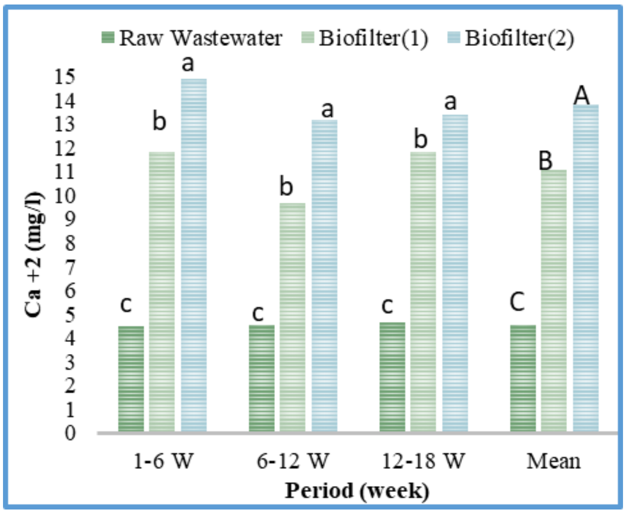

Figure 4. Biofilter effect: 1) Anhydrite and 2) Dolomite on the Ca+2 of the raw wastewater treatment

(2) Magnesium concentration (Mg^{+2})

Magnesium concentration (Mg^{+2})is another indicator of water hardness like calcium. Municipal wastewater can be a potential source of Mg^{+2}. The results showed a significant ($P\leq 0.05$) removal of Mg^{+2} during different treatment periods as can be seen in Figure 5. During the first duration, the average Mg^{+2} concentration of the influent was 5.11 mg/l. After the treatment, Mg^{++} decreased by 61.6% in Anhydrite (1.96 mg/l) and 86.3% in Dolomite (0.70 mg/l) biofilters. In the second period, the treatment led to a higher reduction in Mg^{++} for the treated wastewater by Anhydrite (88%) and 87.8% reduction in Dolomite effluents. The higher removal efficiency in this period might be related to an increase in the degree of temperature in the environment that could affect microorganism metabolism. For the third period, the average Mg^{+2} level in the influent detected at 5.69 mg/l, and after treatment 0.97 mg/l and 0.71 mg/l, in the biofilters 1 and 2, respectively. This indicates that the reduction rate was 83% for

Anhydrite and 87.5% for Dolomite. Approximately the efficiency of the Dolomite biofilter was stable in the third period meanwhile a slight decrease in the efficiency of the Anhydrite biofilter compared to the second period. Over the investigation period, the overall removals of Mg+2 were 77.8% in Anhydrite and 87.15% in Dolomite effluent. These results suggest the superiority of Dolomite against Anhydrite. This might be attributed to the high adsorption capacity of Dolomite [28].

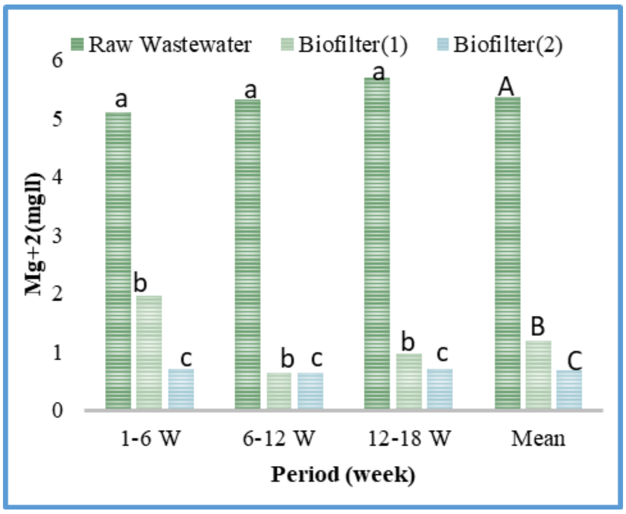

Figure 5. Biofilter effect: 1) Anhydrite and 2) Dolomite on the Mg^{+2} of raw wastewater treatment

(3) Sodium concentration (Na^{+})

Figure 6 shows a considerable drop in Na^{+} concentration in effluent compared to the influent after treatment. At the beginning period, the Na+ content was 11.52 mg/l. After treatment, the Na+ content in effluent from the biofilters dtetected at 5.78 mg/l for Anhydrite and 5.56 mg/l for Dolomite.

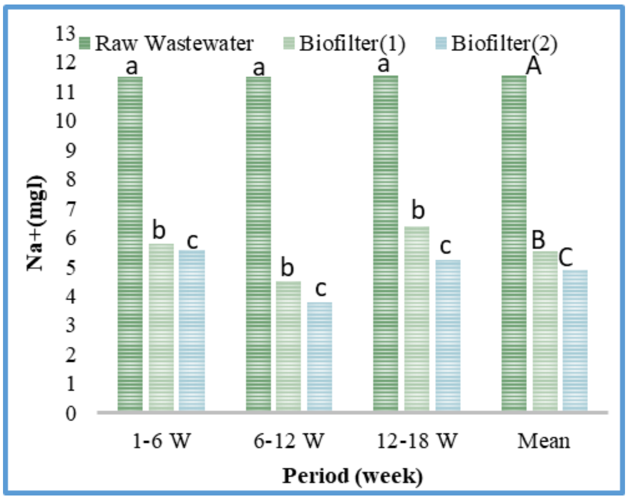

Figure 6. Biofilter effect: 1) Anhydrite and 2) Dolomite on the Na+ of raw wastewater treatment

Similarly, in the second phase, the average Na^{+} level in the raw wastewater was 11.52 mg/l. After the treatment Na^{+} decreased to be 4.52 mg/l and 3.8 mg/l for treated wastewater using Anhydrite and Dolomite, respectively. This indicates that Na^{+} content was reduced by 60.7% in Anhydrite and 67% in Dolomite in treated wastewater. The average concentration of Na^{+} in the influent throughout the third phase was found 11.54 mg/l. After treatment, the biofilter effluents of Anhydrite and Dolomite were an average concentration of Na^{+} 5.25 mg/l and 6.37 mg/l, respectively. This indicates a 54.5% reduction of Na+ in Dolomite and 44.8% for Anhydrite in the effluent. The average Na^{+} content during the 18 weeks was calculated to be 11.53 mg/l in the influent (raw wastewater) and 5.53 mg/l and 4.88 mg/l in the treated wastewater using Anhydrite and Dolomite, respectively. Throughout the influent average, this translates to 52% decrease in Na+ for Anhydrite and 57.76% reduction for Dolomite in the effluent. Adsorption may cause a drop in Na^{+} content in the effluent compared to the influent, according to the study [29]. It was noted that the Dolomite showed the most significant reduction, likely due to its increased surface area. The slightly lower efficiency of the filter in the third phase might be a result of the filter aging.

(4) Potassium concentration (K^{+})

Figure 7 illustrates a significan ($P \leq 0.05$) reduction of K^{+} content in the effluent relative to the influent. During the first period, the concenteration of K^{+} was 0.41 mg.l-1 and then decreased in biofilter effluents to 0.26 mg/l-1 and 0.34 mg/l-1 for Anhydrite and Dolomite. In the second period, K+ was 0.71 mg/l in the raw wastewater, meanwhile after treatment decreased to 0.41 mg/l (42.2%) and 0.28 mg/l (60.5%) the the Anhydrite and Dolomite biofilters, respectively. In the third period, a high loading of K^{+} (1.01 mg/l) was detected in the raw wastewater. In this period the biofilters showed a low removal efficieny of K^{+} by the biofilters compared to the previous phase of the experiment. The effluent values of K^{+} were 0.95 mg/l and 0.63 mg/l with a percentage removal of 6% for the Anhydrite and 37.6% for Dolomite filters. The filter's low efficiency that was seen during the third duration could be attributed to biofilter aging. The effluent showed considerable ($P \leq 0.05$) K^{+} reduction compared to the influent average. Generally, as the average removal efficiency of K^{+} of the three periods of study, the Dolomite filter showed a higher removal efficiency of K^{+} (43.6%) compared to that one achieved by Anhydrite (21.1%) and in Dolomite when compared to the effluent average. The positive adsorption by Dolomite led to a decrease in the level of K^{+} in the effluent after the treatment process using this material [30].

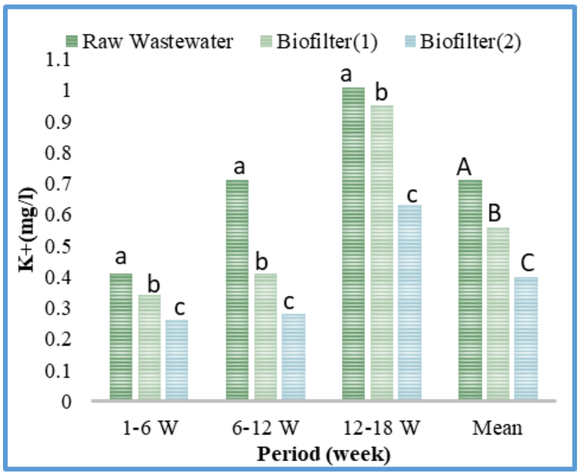

Figure 7. Biofilter effect: 1) Anhydrite and 2) Dolomite in the K^{+} of raw wastewater remedy

3.3.2 Major anions

(1) Bicarbonate concentration (HCO_3^-)

Bicarbonate (HCO_3) is one of the main anions found in untreated natural water. These ions are essential to the carbonate system, which provides natural water with a buffering capacity and is mostly in charge of the water's alkalinity (Hassan 2023). A considerable decrease in HCO_3^- in the effluent compared to the influent shown in Figure 8. In the first period, the content of HCO_3^- decreased from 9.8 in the influent mg/L to 4.18 mg/L (57.3%) and 3.44 mg/L (64.9%) after treatment by the Anhydrite and Dolomite biofliters, respectively. A similar observation was recorded during the second period of the experiment. The Anhydrite and Dolomite effluents recorded 66.27% and 66.1% reomavals of HCO_3^-, respectively. A slight reduction in the efficiency of removal of HCO_3^- was found during the third period, resulting in removals of 53.3% and 56.5% using the Anhydrite and Dolomite filters, respectively. Generally with significant reductrion of ($P\leq0.05$) HCO_3^- was achieved. The overall efficiency removal throughout the the time of the experiment was 61.5% and 63% using Anhydrite and Dolomite biofilters, respectively. The mechanism of removal of HCO_3^- from treated wastewater might be relted to the negative adsorption and precipitation that occur in the media of filter [31].

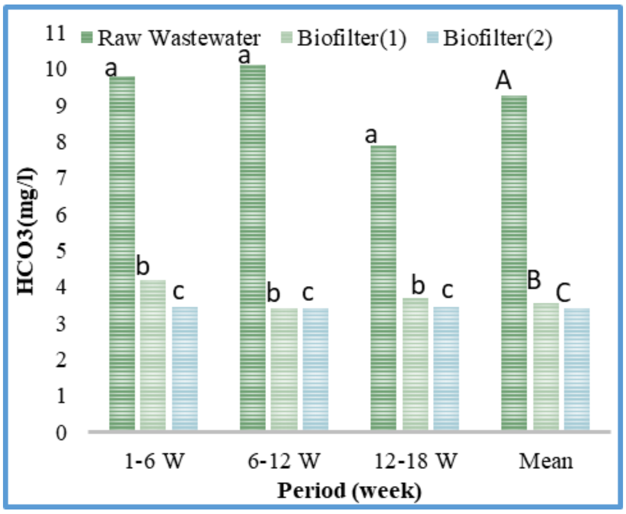

Figure 8. Biofilter effect: 1) Anhydrite and 2) Dolomite on the HCO_3 of raw wastewater treatment

(2) Chloride concentration (Cl^-)

The presence of chloride anions (Cl) in wateror wastewater can represent a serious environmental problem due to its high water solubilityand non-biodegradability. Removing Cl^- from water or wastewater is a challenging process and can be mainly removed through via chemical precipitation, adsorption, oxidation, and membrane separation [32]. Thus finding novel technologies with aviable operation conditions is a necessary objective. The proposed technique in this study showed a significant ($P\leq0.05$) removal in theconcentration of Cl^- during the time of the experiment as shown in Figure 9. In the first period, higher performance was recorded by the Dolomite filter with 90 % removal of Cl^- than 19.66% by the Anhydrite filter. Meanwhile, in the second period, the average Cl^- concentration in the influent was 12.39 mg/l, while in the effluent from the biofilters, as shown in Figure 10, it was 6.92 mg/l and 3.82 mg/l, respectively. This represents reduction rate Cl^- of 44% in Anhydrite and 69% in Dolomite. In the third duration, the average Cl^- concentration in the influent was decreased from 12.66 mg/l to 6.81 mg/l (46.3%)and 3.52 mg/l (72.3%) in Anhydrite and Dolomite filter effluent, respectively. Approximately a similar performance for the second stage was observed in thethird period of the experiment. The removals of Cl^- were 36.7% in the Anhydrite and 77.3% in the Dolomite in the effluent compared to the influent. A decrease in the efficiency of the Dolomite filter was observed in the second and third possibly due to filter aging. Generally performing the treatment using a Dolomite filter revealed a noticeable removal for Cl^- and the average of removals was 80% along the total time of the experiment. On the other hand, the average Cl^- removals was 34.5% in Anhydrite. These results suggest that Dolomite is superior dueto its higher adsorption capability [33].

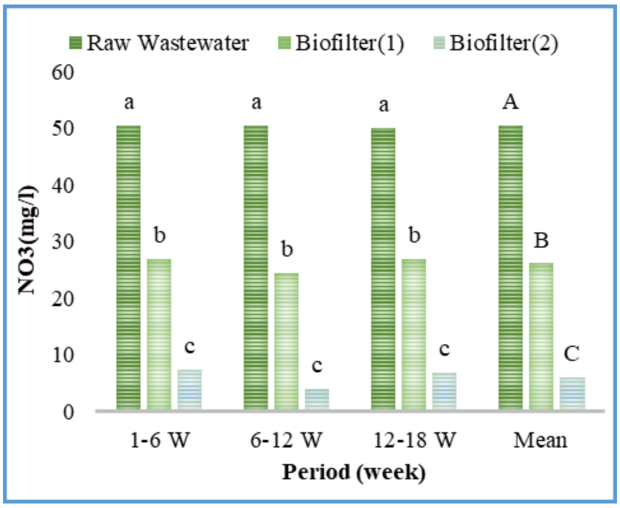

Figure 9. Biofilter effect: 1) Anhydrite and 2) Dolomite on Cl^- of the raw wastewater pretreatment

(3) Nitrate concentration (NO_3^-)

The presence of nitrogen in municipal wastewater is a common matter. Nitrate has a touchable influence on aquatic systems that increase eutrophication. Thus, the removal of this nutrient from the effluent is a significant factor for environmental sustainability. The results showed that higher removal for NO_3^-. The results showed a decrease in the concentration of NO_3^- on the two biofilters as shown in Figure 9.

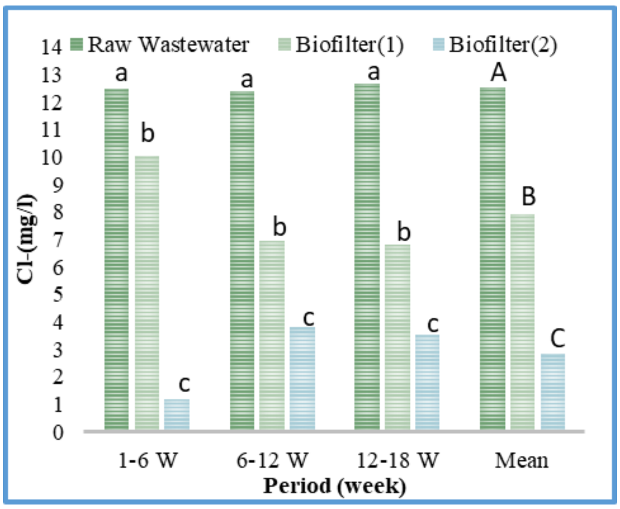

Figure 10. Biofilter effect: 1) Anhydrite and 2) Dolomite on NO^{-3} of the raw wastewater pretreatment

The highest removal rates occurred during the second period of operation (P2, 7-12 weeks) in the spring season (March) range of Temperature almost above the twenties of ºC in this country. In this phase of operation, the Dolomite filter showed a superior removal rate of NO^{-3} compared to the Anhydrite filter. The NO^{-3} removals were 92% and 52% in biofilter 2 (Dolomite) and biofilter 1 (Anhydrite), respectively. For the first and third periods of operation, the Dolomite shows approximately similar removal rates of and higher. Meanwhile Anhydrite filter shows a constant performance for removal of NO^{-3} for all periods of operation around 50%. These results suggest the possibility of using Dolomite for the removal of nitrate from wastewater.

3.3.4 Water quality for irrigation

To evaluate the suitability of treated water for irrigation Sodium Adsorption Ratio (SAR) should be calculated. It represents the relationship between the ions of sodium versus calcium and magnesium as shown in Eq. (1) [34].

$$SAR = \frac{[Na^{+1}]}{\sqrt{\frac{[Ca^{+2}] + [Mg^{+2}]}{2}}} \tag{1}$$

where, sodium ion is represented as $[Na^{+1}]$, calcium ion as $[Ca^{+2}]$, and magnesium ion as $[Mg^{+2}]$. Residual sodium carbonates (RSC) are used to assess water irrigation properties. RSC can be calculated by finding the difference between the sum of carbonate and bicarbonate and the sum of calcium and magnesium in water. Table 5 displays the values of EC, SAR, and RSE for water treated with Anhydrite and Dolomite biofilters. The table also includes the permissible limits for top-quality water. From this table, we can derive the following results: The EC value is 1100 micromhos/cm and 740 micromhos/cm for the Anhydrite and Dolomite biofilters, respectively [18]. Based on Richard's [21] classification of less than 10 ppm, the water treated by the Anhydrite and Dolomite biofilters falls within the "excellent" class for irrigation. The SAR values are 2.1 and 1.73 ppm for water treated by the Anhydrite and Dolomite biofilters, respectively, placing them in the S1 class, indicating top-quality water suitable for irrigation purposes. According to Richards' [21] classification, water with RSC less than 2.5 meq/l is considered suitable for irrigation. The RSE for both biofilters is below 1.25 ppm, indicating that the treated water is suitable for irrigation and even for drinking purposes. Therefore it can recycle the effluents of the propsed process for the irrigation process via adopting designs of scalable treatment plants using dolomite media and biofiltration techniques, especially in rural areas.

Table 5. Values of EC, SAR, and RSC for water treatment by Anhydrite and Dolomite biofilter systems

Class	Units	Anhydrite Biofilter	Dolomite Biofilter	Allowable Limits for Best Quality
EC	$dS.m^{-1}$	1150	740	**100-750**
SAR	epm	2.1	1.73	**<10**
RSC	meq/l	-8.72	-13.83	**1.25>**

4. CONCLUSIONS

This study conducted experiments using two types of biofilters with two different types of media: Dolomite and Anhydrite crushed rock for biofiltration process to treat real domestic wastewater at different operation condition (pH, temperature, flow rate). The experiments were conducted along 18 weeks during various seasons. The results of this study demonstrated the successful application of these techniques in treating domestic wastewater with high efficiency to remove the various pollutants at different environmental conditions. Additionally, the results indicated the superiority of Dolomite media over Anhydrite crushed rock for the removal of most chemical pollutants. As these materials are widely available in affordable price in Iraq. Thus, the results of this study can be adopted by local authorities to develop scalable and sustainable wastewater treatment plants, especially in the areas that suffer from the lack of the wastewater treatment facilities such as the rural areas which facilitate the reuse of the treated water for irrigation purposes. Due to the scope and limitation of the study, the microbial community and its growth need to be studied to provide a clear perspective on the mechanism of metabolic pathways of microorganisms involved in the degradation of the pollutant as a further study. Moreover, it is recommended to test the use of Dolomite rock powder, as its high surface area may offer enhanced adsorption ability, which could increase pollutant removal efficiency. Furthermore, it is suggested to explore the use of local raw materials in Iraq, such as selecting a media with low density, high porosity, and specific surface to test the biofiltration systems with different sources of wastewater such as industrial activates and petroleum refineries, etc.

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