

Adsorption Technique for Drainage Water Treatment

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Abstract. This study evaluated the suitability of an adsorption technique in drainage water treatment for irrigation purposes. The water samples for this study were sourced from different spots of Al-MASAB AL A'AM river. Three different locations (Latifia, Yusufiyah, and Swerah area) were considered in this study. Several studies have reported the use of activated carbon and ion exchangers for water treatment. In this work, a cheap alternative bio-filtration media (activated carbon derived from Apricot stones (ASAC)) was used. Several parameters are required in this technique for various estimations; such parameters include the chemical and physical properties of the water samples (like the pH, ionic concentration, electrical conductivity (EC), and total dissolved solids (TDS)). The Freundlich equations was also applied to study the chemical adsorption process using ASAC. Also calculated were the adsorption constant (k) and the number of adsorbents (n). From the results of this study, the applied process was suitable for the removal of Ca^{+2} , Mg^{+2} and CO_3^{-2} ions from the sampled water.

1 Introduction

The increase in the global population, as well as the improvements in the peoples' way of life, have resulted in an increase in the demand for water. With the adoption of irrigation as a standard agricultural practice in areas with short annual rainfall, the agricultural demands for water have also increased tremendously. The commercialization of agriculture has been restricted in many countries due to water scarcity. The reutilization of drainage water for agricultural purposes can improve farm productivity and contribute to aquifer recharge, thereby saving the cost of drainage water management and the value of the reclaimed fresh water. However, there may be some environmental hazards associated with drainage water irrigation owing to the presence of several pollutants like heavy metals and pathogens in the drainage water. Serious health challenges could emerge from the use of low-quality water for agricultural purposes; it could also result in soil degradation and decreased crop yield [1,2]. Many classifications have been proposed regarding water suitability for irrigation. The classification presented by Richard [3] is based on the relationship between sodium absorption ratio (SAR) and electrical conductivity (EC), while Ayers & Westcot [4] presented a classification that depended on the five groups that represent the hydro-chemical changes, including the salinity, cations and anions concentrations measured in (epm), nutrients measured in (ppm), and the influence of other miscellaneous materials. The classification presented by Don [5] depended on EC, TDS, SAR, and Na concentration [6].

Different natural raw materials can be used to prepare activated carbons. Among the characteristics of activated carbons is high mechanical strength. Activated carbons can be produced from the shells of coconut and other nuts [7] via a chemical activation process. During the preparation of activated carbon from shells, NaOH is used as the activation agent at a high temperature of 700°C [8]. Activated carbon can also be produced from fruit kernels or olive pits [9] via the carbonization of the olive fruit or seeds. Other sources of activated carbon include almond shells via carbonization in N₂ stream, followed by activation in CO₂ stream [10]; plum kernels via carbonization, followed by CO₂ activation [11]; macadamia nuts via high temperature activation at 900°C, followed by a mixture of water, air, and CO₂ streams [12]. Activated carbon can also be produced from almond and olive shells via several methods, such as carbonization in N₂ stream followed by CO₂ activation, direct activation in CO₂, as well as dry air treatment at 300°C followed by CO₂ activation [13].

This study investigated the adsorption characteristics of drainage water using ASAC as adsorbent. During the study, the adsorption isotherms and thermodynamics of ASAC were determined, while the correlation between the isotherm models and the experimental data was determined by fitting the equilibrium data to Langmuir and Freundlich equations. The adsorption mechanism was determined by calculating the thermodynamic parameters. Also studied was the influence of certain parameters (such as the initial concentration of dye, dosage, temperature, and pH) on dye removal.

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2 Study Area

One of the major developmental projects in Iraq is the Al-Masab Al-Aamis project due to its importance in saline water transportation from the reclamation of agricultural land in the center and southern Iraq. This transportation is mediated through an interconnected network of a secondary and major trocar which eventually flow into the general estuary. Saline water and chemical fertilizer residues used in agriculture are also transported to the Arabian Gulf via the Shatt al Basra. Three stations have been chosen in this study: Station No. 1 is AL-Yusfiya city, south of capital Baghdad, about 25 km south; Station No. 2 is Al Latifiya city, about 25 km east from station No. 1, and 35 km south of Baghdad city; and Station No. 3 at Suwayrah city, about 135 km north of Kut governorate and 55 km south of Baghdad city. The latitude and longitude for these stations are (33.033333 °) N and (44.166667 °) E, (33.079408 °) N and (44.251662) E, and (32.925267 °) N and (44.770958 °) E, respectively. Figure 1 showed an aerial view (Google Earth) of the locations of the selected stations.



Figure 1. Google Earth location of the selected stations

3 Experimental

3.1 Preparation of activated carbon from waste apricot stones

To prepare the activated carbons, apricot stones were collected from Baghdad city, crushed and sieved to a particle size range of 2.5×0.75 mm before activation. Chemical activation of the material using H_2SO_4 at moderate temperatures conferred the material with a high degree of micro-porosity and high surface area. A mixture of the material with conc. H_2SO_4 (2:1 wt ratio) was made and heated in an oven at $600^\circ C$ for 1.5 h. Then, the sample was removed from the oven and cooled to room temperature, before being washed with distilled water and later soaked in $NaHCO_3$ solution (1%) to get rid of the remaining acid. The washing process was continued in distilled water until the activated carbon reaches pH 7. The activated carbon was dried for 5 h at $100^\circ C$ and sorted into the desired size ($\leq 75 \mu m$) [14].

3.2 Water sample collection

The water samples were taken from three positions (Latifia, Yusufiyah, and Swerah area) of the Al-MASAB AL A'AM river. Three water samples were taking from each position.

3.3 Adsorption studies and measurements

Several experimental parameters were studied for effects on dye removal. The studied parameters include the initial concentration of dye ($5-15 \text{ mgL}^{-1}$), dosage of the adsorbent ($5-50 \text{ mg}/100 \text{ mL}$), pH ($5-9$), temperature ($10-40^\circ C$), and particle size $\leq 75 \mu m$. The test tubes were stationed in a shaker and allowed to agitate progressively for 0.5 h at $30^\circ C$ and agitation rate of at 250 rpm to obtain a stable concentration. The mixtures were then filtrated through Whatman No 4 filter paper. Equation 1 was used to determine the retained concentration of the solute (q_e/mgg^{-1}) in the adsorbent phase [15]:

$$q_e = \frac{(C_0 - C_e)V}{W_s} \quad (1)$$

where

C_0 = the initial concentration of the solute (mg/L)

C_e = the final concentration of the solute at equilibrium (mg/L)

V = volume of the solution

W_s = the adsorbents' mass (g).

Equation 2 was used to calculate the percentage of removal efficiency.

$$R(\%) = \frac{(C_0 - C_e)}{C_0} * 100 \quad (2)$$

4 Results and Discussion

4.1 Chemical measurements before adsorption

The untreated samples were chemically analyzed for the presence of different elements which can affect the quality of water for irrigation purpose. The samples were analyzed for the following elements: Ca^{+2} , Mg^{+2} , K^+ , Na^+ , Cl^- , CO_3^{-2} , SAR, and TDS. The results are presented in Table 1. a and b.

SAR was calculated using the following equation [16]:

$$SAR = (Na^+ / (\frac{Ca^{+2} + Mg^{+2}}{2}))^{0.5} \quad (3)$$

Table 1. a.Chemical composition of the samples before adsorption

Station No.	Sample No.	pH	Ca ⁺² ppm	Mg ⁺² ppm	CO ₃ ⁻² ppm	Cl ⁻¹ ppm
1	1-1	8.54	41.54	33.76	66.34	7.56
	1-2	8.44	40.98	31.45	63.44	7.12
	1-3	8.14	40.66	30.66	60.43	6.76
2	2-1	8.77	33.66	27.66	55.34	4.54
	2-2	8.67	31.55	25.43	50.12	4.11
	2-3	8.49	30.66	24.53	49.54	3.88
3	3-1	8.66	24.56	19.76	38.54	3.21
	3-2	8.73	23.65	19.11	36.76	3.10
	3-3	8.65	22.77	18.43	43.12	2.98

Table 1. b.Chemical composition of the samples before adsorption

Station No.	Sample No.	K ⁺ ppm	Na ⁺ ppm	SAR	TDS
1	1-1	15.43	198	32.26	4554
	1-2	14.87	175	20.56	4387
	1-3	14.22	166	19.65	4123
2	2-1	16.44	150	19.15	3842
	2-2	13.55	145	19.20	3756
	2-3	13.21	140	18.84	3723
3	3-1	11.76	137	20.57	3432
	3-2	9.65	129	19.72	3389
	3-3	9.12	120	18.69	3278

4.2 Chemical measurements after adsorption

The concentrations of all the ions were re-evaluated after adsorption. It was found that the concentration of all the ions was lower than before adsorption as shown in Table 2. a and b.

Table 2. a.Chemical composition of the samples after adsorption

Station No.	Sample No.	pH	Ca ⁺² ppm	Mg ⁺² ppm	CO ₃ ⁻² ppm	Cl ⁻¹ ppm
1	1-1	7.33	29.43	23.26	46.34	5.36
	1-2	7.29	27.65	21.65	43.44	5.22
	1-3	7.23	23.76	20.56	40.43	4.86
2	2-1	7.37	21.16	19.54	33.34	3.64
	2-2	7.40	20.35	18.65	32.12	3.21
	2-3	7.42	19.96	17.65	31.34	2.78
3	3-1	7.22	18.44	13.36	22.44	2.81
	3-2	7.29	16.43	12.91	21.46	2.13
	3-3	7.34	14.54	11.83	20.72	1.68

Table 2. b.Chemical composition of the samples after adsorption

Station No.	Sample No.	K ⁺ ppm	Na ⁺ ppm	SAR	TDS
1	1-1	11.43	98	19.09	4254
	1-2	10.87	90	12.81	4187
	1-3	10.22	87	13.06	3895
2	2-1	9.44	77	12.06	3765
	2-2	9.15	71	11.36	3556

3	2-3	9.01	70	11.41	3463
	3-1	8.65	58	10.28	3312
	3-2	8.22	55	10.15	3259
	3-3	7.62	53	10.32	3175

By observing the values shown in Tables 1 and 2, it was noticed that all the values of the chemical measurements after adsorption were lower than before adsorption at different rates.

- Note that the values of pH between 8.14-8.73 and 7.23-7.42 before and after adsorption respectively, indicated that the water bases are mild to neutral. The permissible limits for pH values for irrigation water are between 6-8.5 (FAO, 1985).
- The results of SAR before and after adsorption ranged from 18.69-32.26 to 10.32-19.08 ppm. According to the specification (FAO,1994), if the value of SAR is greater than 9 ppm, the irrigation water is suitable for irrigating salinity-resistant plants grown in good permeability and drainage land with the addition of washing water from 20-25% of water consumption for plants.
- The values of TDS ranged between 4554 and 3173 before and after adsorption, respectively. As per specification (FOW,1985), the allowable limit for irrigation is between 0-2000 ppm. This means that the irrigation water is not suitable for irrigation.
- Adsorption using apricot stones activated carbon (ASAC) was observed to be more effective for ions (Ca⁺², Mg⁺², and CO₃⁻²). The adsorption value for Ca⁺² was 75.3% while the percentage adsorption for Mg⁺² and CO₃⁻² were 65.4% and 56.8% respectively, as shown in Figures 2-4 . The other elements had little adsorption values of <20%.

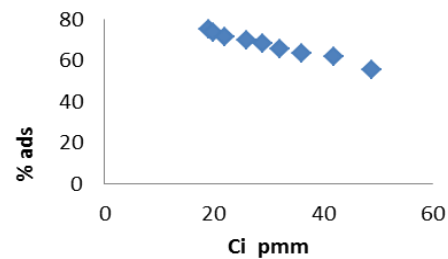


Figure 2. The relationship between concentration and adsorption ratio for Ca⁺².

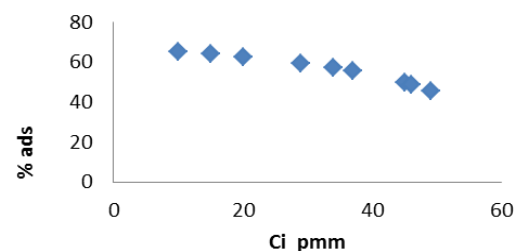


Figure 3. The relationship between concentration and adsorption ratio for Mg⁺².

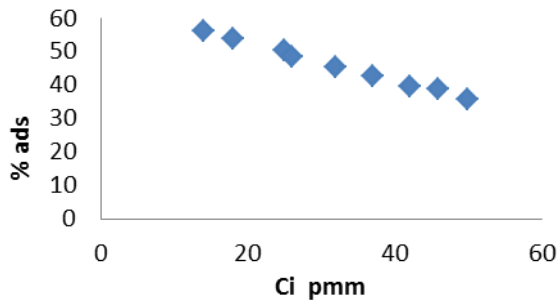


Figure 4. The relationship between concentration and adsorption ratio for CO_3^{-2} .

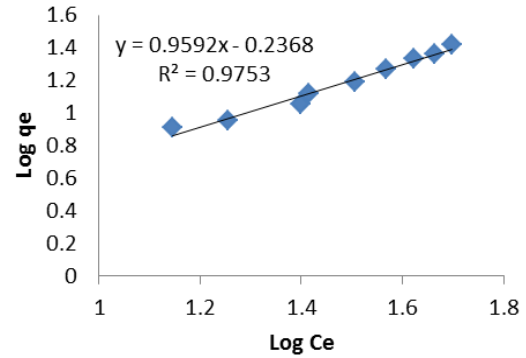


Figure 7. Freundlich adsorption isotherm for CO_3^{-2} .

4.3 Adsorption isotherms

Freundlich isotherm model was used to study the adsorption isotherms. Equation.4 assumes physicochemical adsorption on heterogeneous surfaces.

$$\log q_e = \log K_F + \frac{1}{n \log C_e} \quad (4)$$

Where

K_F and $(1/n)$ = Freundlich adsorption isotherm constants, indicating the extent of adsorption and the adsorption intensity, respectively [17].

The high correlation coefficient value indicates the suitability of the Freundlich isotherm to fit with the equilibrium data as shown in Figures 5-7.

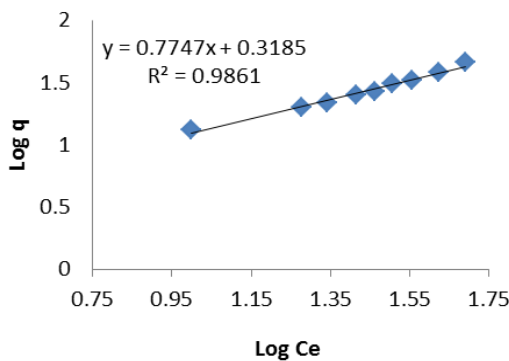


Figure 5. Freundlich adsorption isotherm for Ca^{+2} .

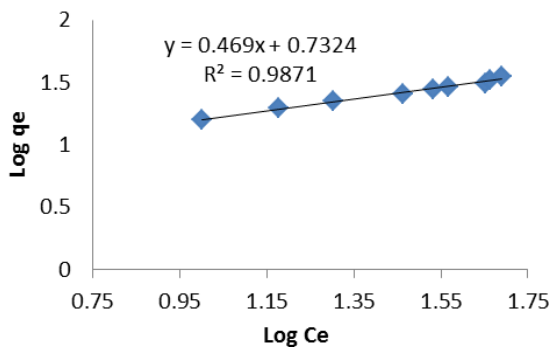


Figure 6. Freundlich adsorption isotherm for Mg^{+2} .

Table 3 presented the isotherm parameters derived from the intercept and slope of the plots.

Ions	K_F	n	R^2
Ca^{+2}	2.08	1.29	0.9861
Mg^{+2}	5.4	2.132	0.9871
CO_3^{-2}	1.043	1.725	0.975

5. Conclusion and Recommendation

The outcome of this study showed that (ASAC) could be used as an adsorbent for the removal of Ca^{+2} , Mg^{+2} and CO_3^{-2} ions from the sampled water. The results also showed that the Freundlich isotherm equation provided the best fit for the experimental data. For future studies use of a cheap alternative bio-filtration medium activated carbon from date seeds (ADS) as an adsorbent for technique in drainage water treatment for irrigation purposes.

The acknowledgments: The author would like to thank Mustansiriyah University (www.uomustansiriyah.edu.iq), Baghdad, Iraq, for its support in the present work. The author also acknowledge the faculty and staff of the Sanatory Laboratory, Environmental Engineering Department, Mustansiriyah University.

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