Treatment of agricultural irrigation water drainage channel by adsorption methods using Sawdust

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Abstract: In this research, the possibility of treating the water of two main agricultural irrigation drainage channels were studied for reuse in irrigation purpose using the adsorption method by activated carbon prepared from sawdust, where the channels included Al-Dawoodi channel that agricultural water drainage and the KSD water channel that agricultural water drainage polluted with wastewater discharged into it from neighboring residential areas. The activated carbon was prepared from sawdust using chemical activation by sulfuric acid H₂SO₄, then operated using Shaker device in three times (30, 90, 210) minutes by dosing (1, 2, 4) gm of activated carbon of sawdust. The results showed that the sawdust has been a essential material in removing contaminants, and suspended solids, from the water of both channels by removing (BOD5, COD, TSS), where for KSD and Al-Dawoodi the BOD5 removal (81%, 85%), COD (79%, 69%), TSS (80%, 90.8%), respectively. The best removal was achieved at the lowest dose (1 gm) within (90 minutes). The use of activated carbon of sawdust led to the removal of unwanted odors of the KSD water channel and an increase in the salts in the water of both channels represented by an increase (EC, TDS, heavy metals (Na, Mg, Ca, Cl, SO₄) and SAR, either the pH were decreased within irrigation standards, so activated carbon of sawdust is considered a pre-treatment of some pollutants with good efficiency.

Keywords: Adsorption, Al-Dawoodi, KSD channel, Irrigation water

1. Introduction
Pollution of agricultural irrigation drainage channels is considered a chemically complex matter in general, and it depends on the source of water flow in the channels, the salts and pesticides used, as it is transported through sub-channels to the main drainage channel [1].

Drainage is defined as the removal of excess water and pesticide residues from agricultural lands to preserve soil properties and this is done through drainage channels, this contributes to improving crop growth, preventing soil salinization, and reducing the accumulation of salts and toxic elements [2].

In Iraq, the idea of constructing drainage channels for excess irrigation water back to the beginning of the nineteenth century when the engineer Sir William Wicklux proposed in 1911 the establishment of the General Company of Al-Musab and continued until the consulting firm TAMS in 1925 studied and implemented drainage projects. Including the Saqlawiya drainage channel [3].

The main agricultural drainage channels are considered among the projects of developmental importance, as their operator in the transfer of salts and pollutants from fertilizers from agricultural lands preserves the permanence of the soil and its properties [4].

Many studies had been taking care of agricultural irrigation water drainage channels for reuse in irrigation purposes, including:
The study of “Abbas et al.” which studied the properties of water of the (Almasabu general) agricultural irrigation drainage channel that included the pH, salinity, and hardness, concluded that the water in the channel is high salinity and hardness, while the pH is within the required standards.

The study of “Al-Khalidi and S. K. Ealaa Allah” investigated the effect of the starch plant on the properties of the Hashemite drainage channel and obtained that plant causing organic pollution resulting from a decrease in the concentration of dissolved oxygen, and the high BOD₅ outside the required range.

The study of “Mohamed” evaluated the efficiency of irrigation and drainage projects in the Kifl state originate the importance of the channel in protecting the soil from the accretion of salt in it and the channel operates in all its branches throughout agricultural lands at a rate medium efficiency.

The treatment of the water of agricultural drainage channels (KSD and Al-Dawoodi) was studied using the multi-media filtration method [8].

KSD is the official name approved without an abbreviation for the agricultural irrigation drainage channel as defined by the Iraqi Ministry of Water Resources

In previous studies on using Sawdust in treating water where:

The study of “Al-Warfali, et al.” studied using Sawdust to remove the methylene blue dye, the result demonstrated the role and efficiency of Sawdust in removing the mentioned dye.

The study of “Khalid and Salman” studied using Sawdust as a cheap and available method for producing active carbon, using physical and chemical activation, potassium hydroxide was used as a catalyst and carbon dioxide, the active carbon was used in the process of adsorption of lead ions in the aqueous solution. The results showed that sawdust has high efficiency of 99% in removing lead ions.

This study aims to the possibility of treating the water of the two main agricultural irrigation drainage channels (KSD and Al-Dawoodi) to be reused for irrigation purposes due to its importance and to achieve water sustainability and reduce agricultural pollutants that are discharged into the water of the Tigris River and Diyala Bridge River into which the water of the two channels drains in it, thus reducing environmental damage, treating with sawdust is available locally and is inexpensive to remove contaminants.

2. Material and Methods

2.1 Study Area

Agricultural drainage channels are important in various regions of the world, due to their effective contribution to removing excess water from plants, soil and reducing the long-term damage resulting from their stay in the soil, thus preserving the physical, chemical, and biological properties of the soil [11]. Channels understudy in this research are included:

2.1.1. Al-Dawoodi main agricultural irrigation drainage water channel. Al-Dawoodi main channel extending from the Rashidiya region north of Baghdad to the lands of Diyala governorate with a length of 27.5 km. The water flows from the agricultural lands to the channel through the branch drainage channels, and the channel’s water drains into the Tigris River from both ends as shown in Figure 1.
2.1.2. **KSD main agricultural irrigation drainage water channel.** The KSD channel is an agricultural drainage channel, but it is polluted with sewage water discharged from neighboring residential areas and the Sadr gas power station. The channel extends from the north of Baghdad in Al-Jazira region, where it flows into the Tigris River, the channel pass through the regions of Sha'ab, Algeria, and Sadr City east of Baghdad, then flows into Diyala Bridge River, with a length of 25 km, as shown in Figure 2.

2.2. **Experiment and Work**

2.2.1. **Preparation of activated carbon.** Treatment was done by adsorption with activated carbon which is a very effective method as it removes different pollutants as it has a surface area. The carbon is activated in two ways, including physical and chemical activation. Chemical activation is done with added acids or basic substances such as (GOH, HCl, ZnCl₂, H₂SO₄, and H₃PO₄) [12]. In this study, chemical activation using sulfuric acid (H₂SO₄) was used:

The step of work included:
- Brought water samples of the two channels, Al-Dawoodi water samples were taken at the station located at latitude 33° 32'35.21" north, and longitude 44° 20'51.56" east, near Al-Sinnari gas station. As for the KSD channel, samples were taken from the station located at latitude 33° 25'57.73 "North and longitude 44° 20'45.74" East. Water samples were collected in plastic containers.
- Sawdust was ground, then dry the powder in the electric oven at a temperature of (105°C) for (1 hr).
- Soaked the sawdust powder with sulfuric acid (H₂SO₄) for (60 minutes) as shown in Figure 3, washing with the regular continuous water tap, then with distilled water until its equivalent to pH (6.9), the powders were dried after activation in an electric oven with a temperature of (105°C) for (1 hr).
- Analyses of (pH, EC, TDS, TSS, BOD₅, COD, the concentration of (Na, Ca, Mg, Cl, SO₄), and SAR) were performed before and after treatment.
- Weighted a quantity of activated carbon prepared from sawdust as a dose (1,2,4 g) in the sensitive balance as shown in Figure 5 and put each dose in a conical flask with 300 ml of agricultural drainage water, the treatment was performed for each water channel separately.
- The conical flasks were put in the Shaker device shown in Figure 4 and operating with (200 rpm), then performing analyses (pH, EC, TDS, TSS) after filtering with filter paper as shown in Figure 5 for each sample after contact time (30, 90, 210) minutes.
- The optimum time was determined at (90 minutes) and then perform analyses of the heavy metal (Ca, Na, Mg, SO₄, Cl), SAR, COD, and BOD₅.
- The equipment used for analyses of water are shown in Table 1:
Figure 3: (A) Sawdust after grinding and drying at (105°C). (B) Sawdust after carbonation. (C) Sulfuric acid.

Figure 4: Activated carbon dose (1,2,4) g with 300 ml of water for each channel separately in Shaker device

Figure 5: (A) Sensitive Balance. (B) paper filter. (C) water filter

Table 1. Instrument use in water analyses

| Instrument                        | Details                  |
|-----------------------------------|--------------------------|
| pH meter                          | WTW-PH3110, Germany      |
| (EC) meter                        | Cond-3110, Germany       |
| Electric Oven                     | Memmert/Germany          |
| TDS meter                         | COM-100, Germany         |
| Atomic-absorption Spectrophotometer AAS | Shimadzu AA-7000 Japan |
| Chemical oxygen demand (COD)      | Lovibond ET 125          |
| Thermoreactor                     |                          |
| COD photometer                    | Lovibond checks it direct COD VARIO |
| BOD                               | WTW-Germany              |
2.2.2 Characterization of activated carbon. XRD and Energy Dispersive X-RAY Spectroscopy (EDS) analyses were performed to characterize the activated carbon components. XRD analysis is one of the methods of accurate structural analysis that is used to identify the crystal stages (polymorphism) of the sample [13]. EDS analysis is an analytical technique through which elemental analysis or chemical characterization of the sample, depended on the interaction between one of the X-ray excitation sources and the sample. Its characterization potential is due to the basic principle that each element has a unique atomic structure that allows for a unique set of peaks on the X-ray emission spectrum [14].

2.2.3. Adsorption study
The removal efficiency of activated carbon prepared from sawdust was calculated using equation (1) as follows:

\[
\% \text{ Removal} = \frac{C_i - C_f}{C_i} \times 100
\]  

Where

- \( C_i \) = initial solute concentration
- \( C_f \) = final solute concentration

The adsorption capacity of the activated carbon at time \( t \), \( q_t \) (mg/g) was determined using equation 2 as follows:

\[
q_t = \frac{(C_i - C_t) \times V}{m}
\]

Where

- \( C_i \) = initial concentration
- \( C_t \) = concentration at time \( t \)
- \( q_t \) = Adsorbed pollutant amount at given adsorbent amount (mg/g).
- \( V \) = water’s volume
- \( m \) = weight of activated carbon (gm).

The adsorption rate at equilibrium (\( q_e \)) was determined using equation (2):

\[
q_e = \frac{(C_i - C_e)}{m \times V}
\]

Where \( C_e \) = concentration of activated carbon at equilibrium.

3. Results and Discussion
3.1. XRD analysis of Activated carbon of sawdust
An XRD test for sawdust was performed before and after the carbon activation process. The examination in Figure (6) shows the presence of a wide peak between 25° and 28° in the carbon of inactive sawdust and after its activation. Additional peaks are noted, confirming the presence of other compounds such as (Calcium Ca, Magnesium Mg, sodium Na, Chlorine Cl, Sulfates SO₄, etc…) in the inactive and inactive samples.
3.2 EDS analysis of Activated carbon of sawdust

EDS analysis showed the composition and concentration of heavy metals in Sawdust before and after the chemical activation process for the preparation of activated carbon in Figure (7). The analyses showed an increase in the concentration of heavy metals (Ca, Na, Mg, So\textsubscript{4}, Cl) after activation of the carbon.

3.3 Effect of contact time and a dose of activated carbon

The effects of contact time on the removal of natural pollutants (salts, organic matter, and suspended solids) using activated carbon prepared from sawdust was a variation in the efficiency of removing the pollutants as shown in Figure (8), it was found through experience that the best results for removing pollutants were achieved at the contact time (90 minutes) at a dose of (1 g) by measuring the removal of (TSS, COD, BOD\textsubscript{5}) for both water channels, where the removal efficiency at 30 min was less, it was observed at increase the time to 210 minutes, the concentration of pollutants began to increase and the carbon efficiency decreased for removal the pollutants, this could be attributed due to the increase in the time from 90 minutes to 210 minutes caused a decrease in the pH, which is one of the main factors that control the removal of compounds in the water, as the change in the pH affects the availability and properties of pollutants in the solution and can modify the chemical state of the functional groups which is responsible for the adsorption, which that explained the lack of removal efficiency when increasing the time, this agrees with the research of “Lara et al.” where found the effect of this on the removal of pollutants, therefore the time (90 minutes is considered the ideal time.

The best removal results were achieved at the lowest dose (1 g), this corresponds to a study “King et al.” which found that increasing the dose of activated carbon did not show any increase in the removal of pollutants, reinforcing that the surface area of the activated carbon used was sufficient to remove the contaminants.

Figure 9) shows the percentage of highest removal was achieved at contact time (90 min) with dose (1 g), (Dose of activated carbon (g) / volume of water (300ml), where TSS (80%, 90.8%), COD (79%, 69%), and BOD\textsubscript{5} (81%, 85%), respectively.

The results are consistent with “Atabaki et al.” and “Koohzad” that found the role of activated carbon in removing TSS and organic matter.

The result also showed an increase in (EC, TDS, and concentration of heavy metal (Na, Mg, Ca, Cl, So\textsubscript{4})), the increase in (Na, Mg, Ca) led to an increase in SAR that calculate by equation (4), the EDS analyses as shown in Figure (7) explained the reason of the increase in heavy metal after activation of carbon where the concentration of (Na, Mg, Ca, Cl, So\textsubscript{4}) was increased, thus this explained the increase in (EC and TDS) that represent the presence of salts.
\[ \text{SAR} = \frac{\text{Na}}{\sqrt{(\text{Ca} + \text{Mg})/2}} \]  

The results are consistent with “Zhuojun Li et al.” that showed increasing the electrical conductivity EC, TDS of treated water after adsorption by activated carbon, explaining this due to that inorganic impurities are consisting of the process of preparing the activated carbon, these impurities separate and dissolve in water, thus increase the conductivity (EC) and TDS of water. Also, the results agree with “Jern” that displayed the ineffectiveness of activated carbon in removing salts, TDS as well as it does not remove heavy metal including Mg, Na, Ca, and a lot of other minerals.
3.4. Effect of pH
The pH is important in the adsorption process as the adsorption of pollutants is affected by changing its value in the solution [21]. The change in pH value is adopted as a result of adsorption without intentionally changing it. The pH value was affected by the dose of activated carbon, the results showed that the best effect of activated carbon was achieved at a dose (1 g). Figure 10 demonstrates the effect of pH on capacitance from the adsorption (TSS, COD, and BOD₅) on activated carbon prepared from sawdust, it was found that the adsorption was effective at pH (7) for KSD channel water and (6.9) for Al-Dawoodi water channel.

3.5 Removal of Odors
When using active carbon prepared from sawdust, all odors of the KSD water channel were removed from the first moments of operation of the Shaker device. The study agrees with “Faruqi et al.” on the role of activated carbon in deodorizing, either Al-Dawoodi water channel was no contain unpleasant odors.
4. Adsorption isotherms

The adsorption isothermal mechanism is explained when molecules are exposed to the adsorption process in solid and liquid phases reach equilibrium. Analysis of the different isotherm data for isotherm models is an essential step in reaching a model suitable for use in design [23]. Various models, including the Langmuir, Freundlich, and BET isotherms, were used to study the adsorption isotherms for removal of (TSS, COD, and BOD₅) as shown in figures (11, 12, 13). The Langmuir model (equation 5) adopts homogeneous monolayer coverage, as well as the same and energetically equivalent adsorption site on the surface of a molecule.

\[
\frac{1}{q_e} = \frac{1}{q_m} + \frac{1}{K_L q_m C_e}
\]  

(5)

Where

- \(q_e\) = amounts of pollutant (mg/g) adsorbed at equilibrium
- \(q_m\) = monolayer adsorption capacity (mg/g)
- \(K_L\) = Langmuir adsorption constant (L/mg) which relates to the free adsorption energy
- \(C_e\) = concentration of activated carbon (mg/L) in the solution at equilibrium.

The Freundlich model (equation 6) assumes physicochemical adsorption on heterogeneous surfaces.

\[
\log q_e = \log K_F + \frac{1}{n} \log C_e
\]

(6)

Where

- \(K_F\) and \(1/n\) = Freundlich adsorption isotherm constants, indicating the extent of adsorption and the adsorption intensity, respectively.

The BET model isotherm (equation 7)

\[
\frac{X}{q_e (1 - X)} = \frac{1}{ab} + \frac{(b - 1)}{ab} X
\]

(7)

Where \(X = C_e/q_e\)

The slope of the plot \(X/q_e (1 - X)\) versus \(X\) gives \((b-1)/ab\) and the intercept yields the adsorption capacity gives \([1/ab]\). The plot of \(X/q_e (1 - X)\) against \(X\).

The best adsorption capacity of the activated carbon was determined at a temperature of 25°C, and pH (7) for the KSD water channel and (6.9) for Al-Dawoodi water at a dose (1g) during (90 min). Table (2) provides constants for equations Langmuir, Freundlich, and BET isotherm where the R² correlation parameter indicates Langmuir suitability as it gave the best fit to the equilibrium data R²= 0.9997 for (KSD channel) and (0.9929) for (AL-Dawoodi channel).

| Isotherm constant | Langmuir | Freundlich | BET |
|-------------------|----------|------------|-----|
| Correlation coefficient/Constants | R² | qm | KL | R² | Log KF | N | R² | qm | KB |
| KSD Water | 0.9997 | 1.26 | 0.025 | 0.8891 | 4.72 | 0.52 | 0.9782 | 0.0063 | 0.0554 |
| Value | Al-Dawoodi water | 0.9929 | 11.13 | 0.021 | 0.9083 | 3.858 | 0.96 | 0.878 | 0.0296 | 0.0713 |

Figure 1: Langmuir adsorption isotherm for (TSS, COD, and BOD$_5$)

Figure 2: Freundlich adsorption isotherm for (TSS, COD and BOD$_5$)
5. Conclusions

The water of the agricultural irrigation drainage channels (KSD and Al-Dawoodi) are the main channels that transport agricultural land water. The research dealt with treating the water of the two channels to re-use it for irrigation purposes. The treatment was carried out using the adsorption method with activated carbon prepared from sawdust. Activated carbon of sawdust showed efficiency in removing suspended solids and organic pollutants represented by (TSS, COD, and BOD<sub>5</sub>), which indicates that it has a good adsorption capacity, as R<sup>2</sup> reached 99.97% when the pH = 7 for the KSD water channel and 99.92% at the pH = 6.9 for Al-Dawoodi water channel at 25° C and contact time of 90 minutes with the lowest dose (1 g). It was also found that activated carbon from sawdust does not remove the salts, and therefore it can be considered as a primary treatment to remove pollutants.

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**Abbreviations**

| EC    | Electrical conductivity | COD     | Chemical oxygen demand |
|-------|-------------------------|---------|------------------------|
| g     | gram                    | BOD<sub>5</sub> | Biochemical oxygen demand |
| TDS   | Total dissolved solids  | SAR     | Sodium adsorption ratio |
| TSS   | Total suspended solids  |         |                        |