Experimental data for aluminum removal from aqueous solution by raw and iron-modified granular activated carbon

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This dataset deals with the modification of granular activated carbon (GAC) with FeCl₃ under basic conditions (pH ≈ 12) for removal of aluminium (Al) from aqueous solution. The structural properties and operational parameters including Al ion concentration (2.15 and 10.3 mg/L), pH solution (2–10), adsorbent dosage (0.1–5 g/L), and contact time (0–10 h) was investigated for raw and modified GAC. This dataset provides information about Al removal by GAC and modified GAC at conditions including: pH = 8, contact time = 6 h, initial Al concentration = 2.15 mg/L. The characterization data of the adsorbents was analysed by Fourier transform infrared (FTIR) spectroscopy, scanning electron microscopy (SEM) and Brunauer, Emmett and Teller (BET) test. The data showed that Freundlich isotherm with and Pseudo second order kinetic model were the best models for describing the Al adsorption reactions. The acquired data indicated that the maximum
adsorption capacity of GAC and modified GAC to uptake Al ($C_0 = 10.3$ mg/L) was 3 and 4.37 mg/g respectively.

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### Specifications Table

| Subject area                  | Environmental Engineering Adsorption |
|-------------------------------|--------------------------------------|
| More specific subject area    |                                      |
| Type of data                  | Table, image and figure              |
| How data was acquired         |                                      |
|                               | - GAC was oxidized by nitric acid and concentrated sulphuric acid. Then it was modified by FeCl₃ · 6H₂O under basic condition according to a designed procedure. |
|                               | - Experiments were conducted according to a designed procedure of analytical test and were investigated in order to perform an analysis of adsorption process. All adsorption tests were done in batch mode. |
|                               | - Fourier transform infrared (FTIR) spectroscopy (Shimadzu 4300), scanning electron microscopy (SEM, Hitachi, SU 70) and Brunauer, Emmett and Teller (BET) tests were used to determine the characteristics of the adsorbent. |
|                               | - The aluminium concentration was measured by DR5000 Spectrophotometer (Method 8012) that was adapted from Standard Methods for the Examination of Water and Wastewater. |
| Data format                   | Raw and analysed                      |
| Experimental factors          | Studying variables including pH, contact time, Al concentration, adsorbent dosage and characterisation of raw and modified GAC which were investigated for Al removal by adsorption. |
| Experimental features         | - Characterization data of raw and modified GAC obtained from FTIR, BET and SEM are given. |
|                               | - Optimization of Al adsorption onto raw and modified GAC adsorbent by modification. |
| Data source location          | Saveh University of Medical Sciences. |
| Data accessibility            | The data presented in this article is not published anywhere else. |

### Value of the data

- The data are beneficial for determination of the isotherm and kinetic for predicting and modelling the adsorption capacity and mechanism of Al removal by the iron-modified GAC.
- These data show the efficacy of modified GAC in comparison to raw GAC on Al removal.
- The dataset will be useful for Al removal from aqueous solution.

### 1. Data

Presented data in this article comprise the characterization of raw and modified GAC (in this paper modified GAC under basic condition nominated as BGAC) with analytical methods like FTIR, SEM, BET and iron content, as well as experimental data including studying different variables (pH, contact time, Al concentration and adsorbent dosage), isotherm and kinetic. One of the best available technologies for pollutants removal from aqueous solutions is adsorption which has a very good efficiency
Table 1 shows the iron content, BET surface area and other related data about the raw and modified GAC. Figs. 1–3 show the data for SEM and FTIR for raw and modified GAC and Fig. 4 represents the experimental procedures. Kinetics and Isotherms equations presented in Tables 2 and 3 and Kinetics data for Al adsorbed onto raw and modified GAC was presented in Table 4. Figs. 5–8 show the removal of Al with raw and modified GAC by different parameters. Figs. 9 and 10 shows the adsorption isotherm for Al removal with raw and modified GAC (BGAC).

2. Experimental design, materials and methods

In this work the removal of Al from water was carried out by raw GAC (supplied by the Merck Company) and modified GAC by FeCl3 under basic pH condition (BGAC). Some wastewater like spent filter backwash water from water treatment plant was discharged to surface or groundwater without any treatment and it was endangered soil, water body and environment [3–8]. So it was necessary for all water treatment plants that treat their wastewater before entering to environment.

2.1. Materials

Analytical grade ferric chloride (FeCl3·6H2O), GAC, sulfuric acid, nitric acid and sodium hydroxide were purchased from Merck Company. Also, AlK(SO4)2·12H2O was used for aluminium stock solution.

| Adsorbent         | Total volume (cm³/g) | BET surface area (m²/g) | Total pore volume (cm³/g) | Average pore diameter (nm) | Fe content a (mg/g) |
|-------------------|----------------------|--------------------------|---------------------------|---------------------------|---------------------|
| Raw GAC           | 217/09               | 944/89                   | 0/4621                    | 1/9564                    | 2.5                 |
| Modified GAC (BGAC) | 136/43               | 593/81                   | 0/3114                    | 2/0979                    | 81.2                |

a Iron content = \( \frac{mass of iron}{mass of GAC} \times 100. \)

Fig. 1. SEM image of raw GAC (A) and modified GAC (B).
Fig. 2. FTIR spectra for raw GAC.

Fig. 3. FTIR spectra for modified GAC.

Fig. 4. Experimental procedure for GAC modification. GAC Modification was including 1: oxidation by both 65% nitric acid and concentrated sulfuric acid, 2: coating of oxidized GAC by FeCl$_3$.6H$_2$O solution containing 2.5% of Fe$^{3+}$ (pH was adjusted to 12 and coating conducted at 80°C for 24 h), 3: calcination at 300°C under a N$_2$ atmosphere for 3 h, 4: production of modified GAC (BGAC). 5: Batch approach.
2.2. Experiment protocol

2.2.1. Preparation of modified GAC

40 g of the oxidized GAC was mixed with 200 mL of FeCl$_3$·6H$_2$O solution containing 2.5% of Fe$^{3+}$ and pH was adjusted to 12 by the addition of 1 N NaOH solution. The impregnation of Fe was carried out at 80 °C for 24 h on shaker with 150 rpm rotation [9]. Impregnated GAC was
calcined at 300 °C under a N₂ atmosphere for 3 h. Then it was washed with distilled water for several times and dried at 110 °C during 24 h [10].

2.2.2. Adsorption experiments

Adsorption experiments were conducted by batch method in a 200 mL Erlenmeyer flask and stirred at 250 rpm in a shaker–incubator instrument. Experiments included determination of optimum pH, equilibrium time, dose of adsorbents, Al concentration, the kinetic studies and adsorption isotherms.

For optimum pH selection, 50 mL of Al solution (C₀ = 10.3 mg/L) introduced in 200 mL Erlenmeyer flasks. Then 0.1 g of the adsorbents was put in contact with 50 mL of Al solution (dose of adsorbent was 2 g/L). The pH was adjusted to 2, 3, 4, 6, 7, 8, 9 and 10 by using 1 M HCl or 1 M NaOH (pH was measured by pH-meter model CG 824). The samples were placed in mechanical shaker for 24 h at the room temperature (20 ± 1 °C) and after that, the combination of Al solution and adsorbents was

Fig. 6. The removal efficiency of Al by raw and modified GAC (BGAC) under different contact time. adsorbents dosage: 2 g/L, Al concentration: 10.3 mg/L, contact time: 24 h and mixing speed: 250 rpm.

Fig. 7. Al removal efficiency by different dosage of raw GAC (0.1, 0.5, 2 and 5 g/L).

Fig. 8. Al removal efficiency by different dosage of modified GAC (0.1, 0.5, 2 and 5 g/L).
Fig. 9. Freundlich isotherm of raw and modified GAC (BGAC). For Part A and B, Al concentration was 2.15 mg/L and adsorbents dose: 0.1, 0.5, 2 and 5 g/L. For Part D and E Al concentration was 10.3 mg/L and adsorbents dose: 0.1, 0.5, 2 and 5 g/L.

Fig. 10. Langmuir isotherm of raw and modified GAC (BGAC). For Part A and B Al concentration was 2.15 mg/L and adsorbents dose: 0.1, 0.5, 2 and 5 g/L. For Part D and E Al concentration was 10.3 mg/L and adsorbents dose: 0.1, 0.5, 2 and 5 g/L.
filtered through Whatman paper (0.45 µm) and the concentration of the residual Al was determined by DR-5000.

Percentage removal of Al and adsorption capacity of adsorbent at time t (qt) were calculated as Eqs. (1) and (2):

\[
\text{Percentage removal} \% = \left[1 - \frac{C_e}{C_0}\right] \times 100
\]

where \(C_0\) and \(C_e\) (mg/L) are the initial and equilibrium solute concentrations, respectively.

\[
q_e (\text{mg/g}) = \left[\frac{C_0 - C_e}{M}\right] \times V
\]

where \(C_0\) and \(C_e\) (mg/L) are the initial and final concentration of Al at time t in the solutions, respectively. \(M\) (g) is the amount of the adsorbent used and \(V\) (L) the volume of Al solution.

To obtain dataset for adsorption equilibrium isotherms, two initial concentrations of Al (2.15 and 10.3 mg/L) and several doses of adsorbents (0.1, 0.5, 2 and 5 g/L) were used at optimum pH (8) and contact time (6 h).

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Transparency document. Supplementary material

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