Data Article

Experimental dataset on acid treated eggshell for removing cyanide ions from synthetic and industrial wastewaters

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Abstract
The data current in this article are associated to the efficacy of acid treated eggshell as eggshell membrane (ESM) as an adsorbent for eliminating cyanide ion from synthetic and industrial wastewaters. This article describes the effects of selected factors such as pH (3–11), contact time (5–60 min), cyanide ion concentrations (50–150 mg/L), ESM dose (0.25–2 g/L), and solution temperature (20–50) on the removal cyanide ion from aqueous solution. The maximum cyanide ion removal obtained at a solution pH of 9–11. The kinetic data agreed with the pseudo-second-order kinetic. The equilibrium adsorption data at different temperatures well set through Langmuir equation. FTIR and thermodynamic data describe main adsorption phenomenon in cyanide ion onto ESM could be the ion exchange and chemisorption.

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Specifications Table

| Subject area          | Environmental engineering |
|-----------------------|---------------------------|
| More specific subject area | Environmental technology and waste management |
**Type of data**
Table, image, and figure

**How data was acquired**
The capability of eggshell membrane to adsorb cyanide ions was conducted using a series of batch tests in a shaker-incubator instrument.

**Data format**
Analysis

**Experimental factors**
Monitoring cyanide ions concentrations under various levels of initial target concentration, pH, adsorbent mass temperature, and reaction time for achieving the optimal conditions to remove cyanide ion from wastewater using eggshell membrane.

**Experimental features**
Cyanide ion adsorption by eggshell membrane and introduce low-cost and applied waste material in wastewater treatment

**Data source location**
Chemistry laboratory water and wastewater, Hamadan University of Medical Sciences, Hamadan, Iran.

**Data accessibility**
Data are accessible in the article

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**Value of the data**

- The data presents a low-cost adsorbent make from waste material of eggshell membrane.
- The isotherm, kinetic and thermodynamic data will be useful and valuable for expecting and modeling the adsorption capacity and mechanism of cyanide ion elimination via the adsorbent. The attained data will be beneficial for the methodical and engineering community that needing to scale up and design an adsorption column with eggshell membrane as bed for the elimination of cyanide ion from water or wastewater.

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1. **Data**

   SEM data for eggshell membrane with different magnification were shown in Fig. 1a, b. Fig. 2a, b displayed EDX spectra data of the fresh eggshells and ESM. Fig. 3 indicated experimental data for point of zero charge (pHZpc) of ESM. Fig. 4 depicted data for the FTIR spectrum of ESM before and after cyanide loaded. Data of the influence of solution pH on cyanide ion removal by ESM is shown in Fig. 5. In Fig. 6 the profile of cyanide removal data as a function of ESM dosage indicated. Fig. 7 demonstrated data of intraparticle diffusion model plot for the adsorption of cyanide onto ESM through different concentrations. Fig. 8 showed the profile of cyanide ion removal data as a function of solution temperature. The parameters obtained from pseudo-first-order model parameters with different initial cyanide ion concentrations are tabulated in Table 1. The parameters obtained from pseudo-second-order model parameters with different initial cyanide ion concentrations indicated in Table 2. The parameters obtained from intraparticle diffusion model with different initial cyanide ion concentrations exhibited in Table 3. In Table 4 the data regarding to Langmuir, Freundlich, Dubinin-Radushkevich and Temkin adsorption isotherm parameters are presented. Thermodynamic data for adsorption of cyanide ion on ESM indicated in Table 5. Table 6 described the quality of electroplating plant wastewater before and after treatment with the ESM.

2. **Experimental design, materials and methods**

   2.1. **Materials**

   In this work, fresh eggshells used were obtained from local confectionary shop. The eggshells were initially washed with tap water and then dried at 105 °C. The dried eggshells were grinded to size 0.5–0.6 mm. To prepare ESM, the eggshells were occupied in the hydrochloric acid (%0.5) for 35 min [1]. The obtained ESM were washed with distilled water and washed ESM was dried in the oven at 80 °C. The stock of cyanide solution (1.0 g CN⁻/L) was prepared by dissolving required quantity of
NaCN in 1.0 L of Milli-Q water. All of chemicals and reagents were of analytical grade that were used without further purification (Merck Co., Germany).

### 2.2. Adsorption tests

The ability of ESM to the cyanide removal was assessed by a series of batch experiments in a shaker-incubator instrument (Pars Azma Co., Iran). For each experimental run, 100 mL of solution having a known concentration of cyanide ion and with the chosen level of pH was first poured into beaker. Then, a fixed mass of ESM was added to vessel and placed inside the shaker-incubator. Next, vessel was mixed at 120 rpm for a given time. Lastly, the suspension of shacked sample was filtrated and analyzed for the concentration remained cyanide ion. The influence of temperature, pH, mixing time, initial cyanide ion concentration and adsorbent mass as variable parameters assessed. Eqs. (1) and (2) were used to determine the cyanide removal efficiency (R) and the adsorption capacity of ESM in each run [2,3].

\[ R(\%) = \left( \frac{C_0 - C_e}{C_0} \right) \times 100 \]  
\[ q_e (\text{mg/g}_{ESM}) = \frac{V}{M} \times (C_0 - C_e) \]  

where \( C_0 \) and \( C_e \) are the initial and equilibrium concentration of cyanide ion, respectively; \( q_e \) is equilibrium cyanide concentration on ESM, \( V \) is the volume of solution and \( M \) is the mass of the used ESM sample.

### 2.3. Analysis and characterization

Chemical composition ESM was investigated using a Philips model XL-30 scanning electron microscope (SEM) with energy-dispersive X-ray microanalysis (EDX). The pH of point of zero charge (pHpzc) for ESM was measured by the method described by Asgari et al. [4]. Fourier transform infrared (FTIR) spectroscopy (Perkin–Elmer spectrophotometer spectrumone) in the range, 450–4000 cm\(^{-1}\) was used to investigate of functional groups on the surface of ESM. The concentration of cyanide ion was determined according to standard method 4500-CN-D of APHA [5].

![Fig. 1. SEM analysis data for make eggshell membrane (a) 10 µm magnification, (b) 1 µm magnification.](image-url)
2.4. Isotherm of cyanide ion adsorption onto ESM

To describe the cyanide adsorption capacity data, obtained isotherm data were fitted by four most commonly used isotherms including Langmuir, Freundlich, Dubinin-Radushkuvich and Temkin. The linear forms of apply isotherms equations can be represented respectively as bellow [5]:

Freundlich equation:  \[ \log q_e = \log K + \frac{1}{n} \log C_e \]  

Langmuir equation:  \[ \frac{1}{q_e} = \frac{1}{q_{\text{max}} \times bC_e} + \frac{1}{q_{\text{max}}} \]  

Fig. 2. EDX spectra of the fresh eggshells (a) and (b) ESM.
Fig. 3. Experimental data for point of zero charge (\(pHzpc\)) of ESM.

Fig. 4. The FTIR spectrum of ESM before and after cyanide ion adsorption.

Fig. 5. The influence of solution pH on cyanide removal by ESM.
Temkin equation: \[ q_e = B \ln K_t + B \ln C_e \] (5)

Dubinin–Radushkevich equation: \[ \ln q_e = \ln q_{\text{max}} - k \varepsilon \] (6)

where \( q_e \) and \( C_e \) are parameters that are described in Eqs. (1) and (2). \( K \) and \( n \) are constants that indicate the adsorption capacity and the adsorption intensity. \( q_{\text{max}} \) is the maximum amount of adsorption (mg/g) and \( b \) is the adsorption equilibrium constant (L/mg). \( \varepsilon \) (Polanyi potential) is \[ RT \ln(1 + (1/C_e)), \] \( q_{\text{max}} \) the adsorption capacity (mg/g), \( k \) a constant related to adsorption energy, \( R \) and \( T \) are the gas constant and temperature (K). \( R_L \) equilibrium constant obtained as follows [5–7]:

\[ R_L = \frac{1}{1 + b C_0} \] (7)

where \( C_0 \) is the initial concentration of cyanide ion.

\( k \) as energy adsorption, calculated from the \( k \) value using the following equation:

\[ E = \frac{1}{\sqrt{2k}} \] (8)

2.5. The kinetic study

To investigate the adsorption mechanism of cyanide removal, the experimental data was fitted with most commonly used pseudo-first- and second-order kinetics model at different experimental conditions. The pseudo first-order kinetic linear equation is generally as follow:

\[ \ln(q_{e,\text{meas}} - q_t) = \ln(q_{e,\text{calc}}) - k_1 t \] (9)

where \( q_{e,\text{meas}} \) and \( q_t \) are experimentally measured and calculated cyanide adsorbed on ESM at time \( t \), \( k_1 \) is the rate constant for pseudo-first-order kinetic. The linear regression analysis of \( \ln(q_{e,\text{meas}} - q_t) \) vs \( t \) for different experimental conditions will give the data of the \( q_{e,\text{calc}} (q_{e,\text{calc}} = \exp(\text{intercept}) \) and \( k_1 (k_1 = -(\text{slop})) \) (8,9).

The pseudo second-order kinetic linear equation is generally as follow:

\[ \frac{t}{q_t} = \frac{1}{k_2 q_{e,\text{calc}}^2} + \frac{1}{q_{e,\text{calc}}} t \] (10)

The value of \( q_{e,\text{calc}} (q_{e,\text{calc}} = 1/\text{slope}) \) and \( k_2 \) as the rate constant (\( k_2 = \text{slope}^2/\text{intercept} \) of the pseudo-second-order equation obtained from linear regression analysis of \( t/q_t \) vs \( t \) [8–10]. Via Weber
and Morris equation was also used to evaluate experimental adsorption kinetic data. The linear form of the equation is as follows [11,12]:

\[ q_t = k_{id} t^{0.5} + C \]  \hspace{1cm} (11)

where \( C \) is the intercept and \( k_{id} \) is the intraparticle rate constant obtained from the slope of the plot of \( q_t \) against \( t^{0.5} \).

Fig. 7. Intraparticle diffusion model plot for the adsorption of cyanide onto ESM by different concentrations (a) 50 mg/L, (b) 100 mg/L, and (c) 150 mg/L of cyanide.
2.6. Thermodynamics study

To explain the mechanism of cyanide adsorption onto eggshells, the thermodynamics parameters associated with the adsorption were determined by using following equation [13]:

\[
\Delta G = -RT \ln K_c
\]  

(12)

\[
K_c = \frac{q_e}{C_e}
\]  

(13)

\[
\ln K_c = -\frac{\Delta H^o}{RT} + \frac{\Delta S^o}{R}
\]  

(14)

Table 1
The parameters obtained from pseudo-first-order model parameters with different initial cyanide ion concentrations.

| Concentration (mg/L) | qₑ,meas (mg/g) | qₑ,calc (mg/g) | k₁ | ARE | APE | SSE | R² | Rate equation (Fitted model) |
|---------------------|----------------|----------------|----|-----|-----|-----|----|-------------------------------|
| 50                  | 49             | 3.3            | 0.072 | 30.5 | 46.67 | 6.77 | 0.865 | ln(qₑ,meas-qₑ)t = 1.939−0.072t |
| 100                 | 94             | 35             | 0.056 | 40.55 | 60.62 | 8.79 | 0.938 | ln(qₑ,meas-qₑ)t = 3.555−0.056t |
| 150                 | 126.6          | 51             | 0.064 | 55.8  | 80.60 | 10.51 | 0.978 | ln(qₑ,meas-qₑ)t = 3.932−0.064t |

Table 2
The parameters obtained from pseudo-second-order model parameters with different initial cyanide ion concentrations.

| Concentration (mg/L) | qₑ,meas (mg/g) | qₑ,calc (mg/g) | k₂ | ARE | APE | SSE | R² | Rate equation (Fitted model) |
|---------------------|----------------|----------------|----|-----|-----|-----|----|-------------------------------|
| 50                  | 49             | 49.5           | 0.044 | 5.77 | 2.33 | 0.078 | 0.999 | t/qₑ = 0.009275 + 0.020t |
| 100                 | 94             | 96.3           | 0.007 | 8.55 | 3.33 | 0.08  | 0.999 | t/qₑ = 0.015405 + 0.010t |
| 150                 | 126.6          | 131            | 0.003 | 8.67 | 4.44 | 0.09  | 0.998 | t/qₑ = 0.019424 + 0.008t |

Table 3
The parameters obtained from intraparticle diffusion model with different initial cyanide ion concentrations.

| Concentration (mg/L) | k₁d | R²  | Rate equation (Fitted model) |
|---------------------|-----|-----|-------------------------------|
| 50                  | 0.616 | 0.867 | qt = 0.616×10.5 + 44.48 |
| 100                 | 3.426 | 0.936 | qt = 3.426×10.5 + 69.34 |
| 150                 | 5.706 | 0.987 | qt = 5.706×10.5 + 85.91 |
Table 4
Langmuir, Freundlich Dubinin–Radushkevich and Temkin adsorption isotherm parameters.

| Isotherm model       | Parameters | Equilibrium temperature (°C) |
|----------------------|------------|-----------------------------|
|                      |            | 20  | 30  | 40  | 50  |
| Langmuir             | $K_L$      | 0.0058 | 0.048 | 0.004 | 0.0043 |
|                      | $q_{max}$  | 166.25 | 169.94 | 188.67 | 294.12 |
|                      | RL         | 0.077 | 0.41 | 0.45 | 0.45 |
|                      | $R^2$      | 0.998 | 0.988 | 0.987 | 0.985 |
|                      | RMSE       | 5.70 | 6.05 | 6.99 | 7.88 |
|                      | $\chi^2$   | 0.26 | 0.55 | 0.78 | 0.89 |
| Freundlich           | $K_F$      | 80.35 | 48.55 | 45.65 | 40.23 |
|                      | $1/n$      | 0.28 | 0.31 | 0.36 | 0.40 |
|                      | $R^2$      | 0.956 | 0.945 | 0.954 | 0.927 |
|                      | RMSE       | 24.35 | 27.67 | 29.89 | 30.55 |
|                      | $\chi^2$   | 28.24 | 34.26 | 38.85 | 39.01 |
| Dubinin–Radushkevich | $K_{DR}$   | 0.002 | 0.004 | 0.008 | 0.007 |
|                      | $E$        | 15 | 11 | 8 | 8.5 |
|                      | $R^2$      | 0.856 | 0.866 | 0.883 | 0.843 |
|                      | RMSE       | 29.63 | 35.81 | 36.73 | 38.67 |
|                      | $\chi^2$   | 42.48 | 45.70 | 46.8 | 50.12 |
| Temkin               | $BT$       | 8 | 12 | 15 | 25 |
|                      | $AT$       | 3.23 | 3.64 | 12.6 | 14.32 |
|                      | $R^2$      | 0.942 | 0.953 | 0.952 | 0.952 |
|                      | RMSE       | 16.45 | 18.17 | 20.78 | 23.34 |
|                      | $\chi^2$   | 5.55 | 8.91 | 12.67 | 14.77 |

Table 5
Thermodynamic data for adsorption of cyanide ion on ESM.

| Cyanide concentration (mg/L) | $\Delta H^\circ$ (kJ/mol) | $\Delta S^\circ$ (kJ/(mol K)) | $\Delta G^\circ$ (kJ/mol) |
|-----------------------------|---------------------------|-------------------------------|---------------------------|
|                             |                           |                               |                           |
| 293                         |                           |                               |                           |
| 303                         |                           |                               |                           |
| 313                         |                           |                               |                           |
| 323                         |                           |                               |                           |

Table 6
The quality of electroplating plant wastewater before and after treatment with the ESM (ESM amount: 0.5 g/L and contact time: 60 min).

| Parameters   | Unit | Raw wastewater | Treated wastewater |
|--------------|------|----------------|--------------------|
| Cyanide      | mg/L | 76             | < 0.2              |
| BOD<sub>5</sub> | mg/L | 151            | 45.1               |
| pH           | –    | 7.8            | 7.7                |
| Turbidity    | NTU  | 6              | 4                  |
| Nitrate      | mg/L | 12             | 10                 |
| Chromate     | mg/L | 19             | 3                  |
| Sulfate      | mg/L | 183            | 179                |
| Salinity     | %    | 0.96           | 0.91               |
2.7. Validity of adsorption isotherm and kinetic study

The applicability of the isotherm equations and kinetic models were evaluated by the correlation coefficient and also comparing residual root mean square error (RMSE) and the chi-square test \( (\chi^2) \) (3, 15) which can be described as:

\[
RMSE = \sqrt{\frac{1}{n-2} \sum_{i=1}^{N} (q_e,\text{meas} - q_e,\text{calc})^2}
\]  

\( (15) \)

\[
\chi^2 = \sum_{i=1}^{N} \frac{(q_e,\text{meas} - q_e,\text{calc})^2}{q_e,\text{calc}}
\]  

\( (16) \)

The correlation coefficient \( (R^2) \) and also the average relative error (ARE), the sum of squares error (SSE) and the average percentage error (APE) in the kinetics studies use to the validity of kinetic models data and they were calculated by following Eqs:

\[
ARE = \frac{\sum_{i=1}^{N} \left( q_e,\text{meas} - q_e,\text{calc} \right)}{q_e,\text{meas}}
\]  

\( (17) \)

\[
SSE = \sum_{i=1}^{N} (q_e,\text{calc} - q_e,\text{meas})
\]  

\( (18) \)

\[
APE = \frac{\sum_{i=1}^{N} \left( (q_e,\text{meas} - q_e,\text{calc}) / q_e,\text{meas} \right)}{N} \times 100
\]  

\( (19) \)

where \( q_e,\text{meas} \) is the observation from the batch experiment \( i \) and \( N \) is the number of measurements made. Upon completion of the basic adsorption experiments, data of the efficacy of ESM in the removal of cyanide ion from industrial wastewater was evaluated. For this, a bulk wastewater sample was obtained from a local electroplating plant.

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**Transparency document. Supporting information**

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References

[1] W. Wang, B. Chen, Y. Huang, J. Cao, Evaluation of eggshell membrane-based bio-adsorbent for solid-phase extraction of linear alkylbenzene sulfonates coupled with high-performance liquid chromatography, J. Chromatogr. A 1217 (2010) 5659–5664.
[2] B. Ramavandi, Behaviour of cyanide adsorption onto lawn waste from aqueous solution and real wastewater, Ecol. Environ. Conserv. 21 (2015) 2081–2089.
[3] M. Fouladvand, B. Ramavandi, Adsorption potential of NH4Br-soaked activated carbon for cyanide removal from wastewater, Indian J. Chem. Technol. 22 (2014) 183–193.
[4] G. Asgari, B. Ramavandi, L. Rasuli, M. Ahmadi, Cr (VI) adsorption from aqueous solution using a surfactant-modified Iranian zeolite: characterization, optimization, and kinetic approach, Desal. Water Treat. 51 (2013) 6009–6020.
[5] APHA, AWWA, WEF, Standard Methods for the Examination of Water and Wastewater, 21st ed., APHA, Washington, DC (2005) 201.
[6] G. Asgari, B. Roshani, G. Ghanizadeh, The investigation of kinetic and isotherm of fluoride adsorption onto functionalize pumice stone, J. Hazard. Mater. 217–218 (2012) 123–132.
[7] G. Asgari, B. Ramavandi, S. Sahebi, Removal of a cationic dye from wastewater during purification by Phoenix dactylifera, Desalin. Water Treat. 52 (2014) 7354–7365.
[8] B. Ramavandi, M. Jafarzadeh, S. Sahebi, Removal of phenol from hyper-saline wastewater using Cu/Mg/Al-chitosan- H2O2 in a fluidized catalytic bed reactor, React. Kinet. Mech. Catal. 111 (2014) 605–620.
[9] M. Shams, I. Nabipour, S. Dobaranaran, B. Ramavandi, M. Qasemi, M. Afsharnia, An environmental friendly and cheap adsorbent (municipal solid waste compost ash) with high efficiency in removal of phosphorus from aqueous solution, Fresenius Environ. Bull. 22 (2013) 722–726.
[10] G. Asgari, A.M. Seid Mohammadi, A. Poormohammadi, M. Ahmadian, Removal of cyanide from aqueous solution by adsorption onto bone charcoal, Fresenius Environ. Bull. 23 (2014) 720–727.
[11] S.D. Ashrafi, H. Kamani, A.H. Mahvi, The optimization study of direct red 81 and Methylene blue adsorption on NaOH-modified rice husk, Desalin. Water Treat. 57 (2) (2016) 738–746.
[12] S.D. Ashrafi, H. Kamani, H. Soheil Arzomand, N. Yousefi, A.H. Mahvi, Optimization and modeling of process variables for adsorption of Basic Blue 41 on NaOH-modified rice husk using response surface methodology, Desalin. Water Treat. 57 (30) (2016) 14051–14059.
[13] S.D. Ashrafi, H. Kamani, J. Jaafari, A.H. Mahvi, Experimental design and response surface modeling for optimization of fluoroquinolone removal from aqueous solution by NaOH-modified rice husk, Desalin. Water Treat. 57 (35) (2016) 16456–16465.