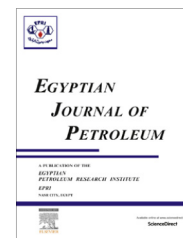




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FULL LENGTH ARTICLE

Adsorption of heavy metal ion from aqueous solution by nickel oxide nano catalyst prepared by different methods



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Abstract Environmental pollution by heavy metal is arising as the most endangering tasks to both water sources and atmosphere quality today. The treatment of heavy metals is of special concern due to their recalcitrance and persistence in the environment. To limit the spread of the heavy metals within water sources, nickel oxide nanoparticles adsorbents were synthesized and characterized with the aim of removal of one of the aggressive heavy elements, namely; lead ions. Nano nickel oxide adsorbents were prepared using NaOH and oxalic acid dissolved in ethanol as precursors. The results indicated that adsorption capacity of Pb(II) ion by NiO-org catalyst is favored than that prepared using NaOH as a precipitant. Nickel oxide nanoparticles prepared by the two methods were characterized structurally and chemically through XRD, DTA, TGA, BET and FT-IR. Affinity and efficiency sorption parameters of the solid nano NiO particles, such as; contact time, initial concentration of lead ions and the dosage of NiO nano catalyst and competitive adsorption behaviors were studied. The results showed that the first-order reaction law fit the reduction of lead ion, also showed good linear relationship with a correlation coefficient (R^2) larger than 0.9.

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1. Introduction

Revelation to heavy metals, even at trace levels, is harmful to human beings [1–4]. Thus, removal of undesirable metals from water sources is considered as an important task that is still

threatening the environment. As the tolerable limit of lead in drinking water is 0.05 mg l^{-1} [5], the presence of excess lead ions in drinking water causes severe diseases such as anemia, encephalopathy, and hepatitis. Lead ions are characterized by an eager affinity towards ligands containing thiol and phosphate groups that inhibit, in turn, the biosynthesis of heme, causing physiological damage to both the kidney and liver; similar to that of calcium. However, Pb can remain immobilized and retarded for long periods and hence it's after effects

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on the function of the human organs are detected on the metabolic disorders, it causes, but after a lag time.

Numerous methods are reported as efficient for the removal of heavy metal ions from water sources, including chemical precipitation, ion exchange, adsorption, membrane filtration and electrochemical technologies [6–11]. Among these techniques, adsorption offers flexibility in design and operation and, in many cases it generates high-quality treated effluents. In addition, owing to the reversible nature of most adsorption processes, adsorbents could be regenerated by suitable desorption processes for multiple use [12]. In addition, many desorption processes are of low maintenance cost, high efficiency, and ease of operation [13]. Therefore, the adsorption process is considered as one of the major suitable technique for heavy metals removal from water/wastewater sources.

Currently, nanosized metal oxides (NMOs), including nanosized ferric oxides, manganese oxides, aluminum oxides, titanium oxides, magnesium oxides and cerium oxides, are classified as promising adsorbents for heavy metal removal from aqueous systems [14–17]. The size and shape of NMOs are considered as the most influential factors with regard to their adsorption performance. In the present work, systematic laboratory investigations for the removal of Pb(II) ions from aqueous solutions through adsorption by nano NiO, prepared by two different precursors were performed for maximum Pb ion removal.

2. Materials and methodology

2.1. Lead ion solution adsorbate

A stock solution of Pb(II) (1000 ppm) was prepared by dissolving the calculated quantity of $\text{Pb}(\text{NO}_3)_2$ for Pb(II) in deionized water.

2.2. Nano NiO adsorbent

2.2.1. Preparation of NiO by precipitation method

The metal hydroxide is firstly prepared by the slow addition of 0.1 M NaOH to the same volume of 0.1 M Nickel nitrate solution with vigorous stirring. The produced hydroxide precipitates are then filtered and then dried at 100 °C overnight. The dried hydroxide was then calcined at 400 °C for 2 h in order to acquire the corresponding NiO catalyst designated in the present work as (NiO_{ppt}).

2.2.2. Preparation of NiO by organic solvent method

Solution of 1 M oxalic acid, dissolved in ethanol, was added to the same volume of 0.2 M nickel nitrate, dissolved also in ethanol solution, with vigorous stirring. The precipitate was then washed with ethanol several times until the filtrates become colorless, then finally washed with acetone and dried at room temperature. The product was then calcined at 400 °C for 1 h to acquire the corresponding NiO catalyst [18], designated in the present work as (NiO_{org}).

2.3. Chemicals

All the chemicals were of analytical-reagent grade.

2.3. Chemical and structural characterization apparatus

Perkin-Elmer 2380 atomic absorption spectrometer was used for the determination of lead using a flame type air/acetylene, while FT-IR spectra were obtained by Perkin Elmer 1000 with a resolution of 4 for the chemical identification of reactants and products. Philips 1390 X-ray powder diffractometer was used for structural identification and Quantachrome Corporation Autosorb-1-C/MS was used for BET surface area determination.

2.4. Adsorption experiments

Batch adsorption experiments of the lead ion adsorption by nano NiO_{ppt} and NiO_{org} adsorbents were carried out at room temperature by shaking a series of bottles each containing the desired quantity of the adsorbent in a predetermined concentration of heavy metal solution. Samples were withdrawn at different time intervals; the supernatant was separated by filtration and analyzed for remaining heavy metal content. The percent removal of heavy metal from solution was calculated by the following equation:

$$\% \text{Adsorption} = \frac{C_o - C_e}{C_o} \times 100$$

where; C_o is initial concentration of heavy metal, C_e is final concentration of heavy metal.

2.5. Adsorption isotherms

The adsorption isotherm that describes the adsorption pattern between the Pb adsorbed metal ions on the nano NiO adsorbent and the residual metal ions in the solution during the surface adsorption was conducted. Equilibrium isotherms are measured to determine the capacity of the adsorbent for metal ions. The most common types of models describing this type of system are the Langmuir and Freundlich models [19]. The adsorption capacity q_e (mg/g) after equilibrium was calculated by a mass balance relationship equation as follows:

$$q_e = (C_o - C_e) \frac{V}{W}$$

where C_o is the initial and C_e is the equilibrium concentrations of the test solution (mg/L), V is the volume of the solution (L) and W is the mass of adsorbent (g).

2.5.1. Langmuir model

Langmuir adsorption model is based on the assumption that the maximum adsorption corresponds to a saturated monolayer of solute molecules on the adsorbent surface. Langmuir equation can be described by the linearized form [18],

$$\frac{1}{q_e} = \left(\frac{1}{q_m k_L} \right) \cdot \left(\frac{1}{C_e} \right) + \frac{1}{q_m}$$

where, C_e is the equilibrium concentration of metal ions in solution (mg/L), q_e is the amount of metal ion adsorbed on adsorbents (mg/g), and q_m and k_L are the monolayer adsorption capacity (mg/g) and Langmuir equilibrium constant (L/mg) which indicates the nature of adsorption, respectively. The

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