Demetallization of Nickel from Crude Oil using Aluminum Oxide (Al₂O₃) Nanoparticles Synthesized with Sodium Dodecyl Sulfate (SDS)

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Abstract

Aluminum oxide nanoparticles (Al₂O₃+SDS and Al₂O₃) were synthesized by a simple sol-gel method for demetallization of nickel from crude oil-water mixture in a batch adsorption process for the first time. The samples were dried, calcined at 550°C, cooled and characterized using scanning electron microscopy (SEM), Energy dispersive spectroscopy (EDS), and X-ray diffraction (XRD) techniques. The XRD confirmed that Al₂O₃ phase were synthesized with more minor impurities of bauxite and silica in Al₂O₃ without SDS. Particle size estimations were 197 and 183 nm for the Al₂O₃ with and without SDS, respectively. SEM showed larger rectangular porous crystallites and thinner net-like-vertical platy crystallites for the former and later samples respectively while the EDS confirmed the presence of Al and O in them. The batch adsorption showed that the %Removal (%R) of the adsorption process increase gradually with increase in adsorbent from 0.02 to 0.1 g to a maximum at 86.1% for Al₂O₃+SDS but decrease with increase in the adsorbent dosage for Al₂O₃, with %R maximum of 78% at the least (0.02 g) dosage. On the other hand, at constant adsorbent dosage, %R of 94 and 95% for a 1:3 crude oil-water mixture were obtained for Al₂O₃+SDS and Al₂O₃, respectively. This confirmed greater capacity of Al₂O₃+SDS for the removal of Ni²⁺ ions from crude oil over the control.

Keywords: Demetallization; Al₂O₃; Al₂O₃+SDS; Ni²⁺; Langmuir and Freundlich

Nomenclature

C₀: Initial Ni²⁺concentration (mg/ml)
Cₑ: Equilibrium concentration of Ni²⁺ in solution (mg/ml)
Kₐ: Langmuir constant (l/mg)
Kₐ: Freundlich constant (mg/g)
K₁: Pseudo first-order adsorption rate constant (l/min)
K₂: Pseudo second-order adsorption rate constant (g/mg min)
M: Weight of adsorbent (g)
n: Freundlich constant gives an indication about the favorability of the adsorption process
qₑ: Adsorption capacity at equilibrium (mg of Ni²⁺ g adsorbate)
qₑ: Langmuir constant related to the maximum adsorption capacity (mg/g)
qₜ: Adsorption capacity at time t (mg of Ni²⁺ g adsorbate)
%R: PERCENTAGE removal (efficiency of Ni²⁺ removal)
R²: The essential features of a Langmuir isotherm/dimensionless constant
R: Correlation coefficient
T: Contact time (min)
V: Volume of the solution (l)

Introduction

Crude oil (also called petroleum) is the major source of energy and devastating environmental pollution in Nigeria [1,2]. This is because crude oil contains some heavy metals such as lead, nickel, iron, vanadium, cobalt, zinc, etc. Naturally occurring elements in rock formations enter reservoir crude oil by complexing with chlorophyll residues (porphyrin) during migration/formation processes [3]. They are often present in small amounts in mgg⁻¹ or ngg⁻¹ range yet pose great concern to the petroleum industry and to the environment due to their ability to accelerate corrosion of distillation towers and turbines, poison catalysts by pore clogging, fissure and deform reactors, pollute the environment, upset natural environmental balances, contaminate food, etc. [4,5]. Demetallization, which has to do with the removal of these metal ions, is therefore a statutory process to enhance efficiency in the oil industry. Among the heavy metals found in crude, nickel determination after demetallization is crucial being constituent of catalysts used in refining processes [4].

Some of the techniques employed for demetallization include coking and hydro treatment [6], microwave-chemical method [7] and most recently, the use of metal oxide nanoparticles, Starch Stabilized Magnetic Nanoparticles (SSMNPs) for the removal of nickel from crude oil monitored by UV-Vis spectrophotometry [5]. The UV-V is method reported dissolved 0.2 ml of the filtrate in 10 ml of hexane for analysis. While the previous methods were considered less effective and expensive, the use of SSMNPs with a high efficiency of 93% was quite promising. However, the report recorded some anomalous values at certain concentrations of the starch coating. Similar use of Gama-Al₂O₃ nanoparticles has been applied for the adsorption of asphaltenes from crude oil-water mixture [8].

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heavy oil but not for demetallization target [8]. Some metals could be removed during deasphaltention by these nanoparticles but not yet investigated.

Aluminum oxide (Al₂O₃) is one of the essential metal oxides because of its broad applications in adsorbents, composite materials and catalyst supports [9,10]. Aluminum oxide (Al₂O₃) nanoparticles could play effective roles in the demetallization of metal ions from crude oil. This is because it has high surface area and catalytic properties. Al₂O₃ nanoparticles do not only adsorb hazardous chemicals but also convert them into smaller and less harmful by-products [11]. In addition, surface modification with surfactants may produce similar enhancement effect reported for starch coated magnetite nanoparticles. Therefore sodium dodecyl sulphate (SDS), an anionic surfactant that could enhance particle growth, coagulation and flocculation will be used for Al₂O₃ nanoparticles synthesis and applied for the demetallization of nickel from crude oil [11]. In this report, the monitoring of removal efficiency of total sample filtrate from each adsorption process with Atomic Absorption Spectrophotometry (AAS) in place of UV-Vis will also be reported.

Materials and Methods

All the reagents used were of analytical grade. Aluminum Chloride hexahydrate (AlCl₃·6H₂O), Sodium hydroxide, (NaOH), Sodium dodecyl sulphate (SDS), triethanolamine (TEA) and ethanol (C₂H₅OH) were all purchased from Aldrich. Almost all the reagents were used as received without further purification except SDS that underwent conductivity test to verify its purity using the value of its critical micelle concentration (CMC). The reagents used for crude oil digestion were potassium permanganate (K₂MnO₄) and conc. (HCl, HNO₃, and H₂SO₄). The crude oil sample was collected with amber bottle (to avoid light interaction) from Qua-Ibo Ocean Terminal Location, SBM, AkwaIbom State of Nigeria on the 5th of July, 2015 and brought to Chemistry laboratory.

Synthesis of Al₂O₃+SDS and Al₂O₃ nanoparticles

A modified Cabrera [9] method was used in the synthesis of the aluminum oxide, Al₂O₃ nanoparticles (sample) according to the following steps: (i) A 5.0 ml solution containing 1.0 g (20 mmol) of sodium hydroxide in deionized water was added to 20 ml of Triethanolamine (TEA). The solution was heated at 120°C for 5 min to evaporate the water. This was followed by a slow addition of 0.49 g (20 mmol) ofAlCl₃·6H₂O into the solution while stirring. The resulting clear solution was kept at 150°C for 10 min (solution A). (ii) The second solution was prepared by dissolving 2.64 g (10 mmol) of sodium dodecyl sulphate in 20 ml of water at 60°C (solution B) (iii) Solution A was gradually added to solution B with continuous stirring at 60°C. The mixture was allowed to age for 72 h to give a white suspension (solution C). Solution C was filtered and the residue (white solid) obtained from the mixture was washed with ethanol and allowed to dry at 30°C. The synthesized Al₂O₃+SDS were calcined in air at 550°C for 5 h in a muffle furnace. The modifications involved the use of AlCl₃·6H₂O and SDS in place of AlCl·6H₂O and cetyltrimethyl ammonium bromide (CTAB), respectively. The control sample, Al₂O₃ was synthesized using the same procedure without SDS.

Characterization (XRD, SEM and EDS): The X-ray diffraction (XRD) analysis of the samples was performed with the Mini-flex Rigaku XRD model equipped with PC-APD diffraction software. The operator could only generate indexed spectra images not text files. The radiation source was Cu Kα (λ=1.54 Å). The 2θ range selected was 6-84° with a step size of 0.02 for 0.25 s per step. Particle size estimations were evaluated according to Scherrer's equation [5]. Few powder particles of the samples were placed on conductive carbon sticky pads with a spatula and gunned unto aluminum stubs for Scanning Electron Microscopy (SEM) analysis. The SEM used was Hitachi model 5.5500 integrated with Energy Dispersive X-ray Spectroscope (EDS).

Pretreatment of the crude oil: (acid digestion)/AAS analysis: Determination of metal contents of Qua-Ibo crude oil was done using the AA500 (PG INSTRUMENTS) AAS model. Samples for AAS analysis were subjected to pretreatment. This involved the oxidation of 1.0 g of homogenized crude sample (analyte) with 1.0 g of potassium permanganate powder in a beaker. Thereafter, 1.0 ml of conc. H₂SO₄ was added to the mixture. A strong exothermic reaction was observed as the crude oil matrix oxidized with evolution of gases. The beaker and its content were allowed to cool, then 2 ml of conc. HNO₃ and 10 ml of conc. HCl were added, and the mixture heated until there was no more evolution of toxic gases at temperatures below 150°C to avoid volatilization. The mixture was filtered and the filtrate heated to drive off excess HCl. The resulting solution was then transferred to a 100 ml volumetric flask and the volume made up with distilled water. A 0.6 mg of the analyte solution was aspirated into the AAS machine for metal (nickel) content determination.

Batch adsorption studies

The synthesized Al₂O₃+SDS and Al₂O₃ were applied in the adsorption of metal ions (Ni²⁺) from the crude oil sample using the batch adsorption method using a mechanical shaker set at 300 rpm. The factors influencing the kinetics of (Ni²⁺) removal by Al₂O₃, with and without SDS were investigated. Such factors include agitation time (contact time), adsorbent concentrations (Al₂O₃+SDS and Al₂O₃), and initial Ni²⁺ ion concentration (adsorbate/crude oil concentration).

Effect of agitation time: The agitation time was investigated separately for both samples at different time intervals of 5, 30, 60, 90 and 120 min at constant adsorbent concentration (0.1 g). The total volume of the solution used was 20 ml comprising of a 5:15 ratio of water/crude oil. It was mechanically shaken at 300 rpm.

Effect of adsorbent concentration (Al₂O₃ dosage): The effect of adsorbent was carried out at different concentrations of 0.02, 0.04, 0.06, 0.08 and 0.10 g of each adsorbent (Al₂O₃+SDS and Al₂O₃, respectively) using the same water - crude oil sample of 5:15 v/v respectively.

Effect of initial Nickel (Ni²⁺) ion concentration (crude oil adsorbate dose): The effect of adsorbate concentration (volume of crude oil) on sorption of Ni²⁺ ion was studied at constant weight (0.10 g) of the adsorbent with varying ratios of crude oil to water as 5:15, 10:10 and 15:5 ml respectively at an agitation time of 2 h. The resulting mixture of oil/H₂O sample was left to stand for 24 h in order to facilitate the separation of the different layers. The water was carefully separated from the crude oil layer and the crude oil analyzed for the Ni²⁺ ion after acid digestion. The amount of Ni²⁺ ion remaining in the crude oil was determined and used in the calculation of percentage removal (% R) as shown in eqns. (1).

\[
\% R = \frac{C_{\text{initial}} - C_{\text{final}}}{C_{\text{initial}}} \times 100
\]

Where C_{\text{initial}} and C_{\text{final}} are initial and final concentrations of nickel ions (µg/ml) respectively.

Adsorption kinetics

The demetallization of nickel ion by the synthesized Al₂O₃...
nanoparticles with and without SDS was studied using the pseudo first (Lagergren) and second order kinetics as expressed in eqns. (2) and (3) respectively

\[ \ln\left(\frac{q_e}{q_t}\right) = \ln q_e - K_1 t \]  
\[ \frac{t}{q_t} = \frac{1}{K_2 q_e^2} + \frac{1}{q_e} \]  

From eqns. (1), q and q represent the amount of Ni\(^{2+}\) adsorbed by the nanoparticles (mg/g) at equilibrium and at any time t (min) respectively, K\(_1\) (Min\(^{-1}\)) is the rate constant of the pseudo-first-order. A linear plot of ln (q\(_e\)-q\(_t\)) against t (time) produce a slope for the evaluation of the rate constant, K\(_1\) while the correlation coefficient R\(^2\) values were generated from data with excel software. In eqns. (2) (pseudo-second-order), K\(_2\) (g/mg/min) is the rate constant of adsorption, q\(_e\) and q\(_t\) are the amounts (mg/g) adsorbed at equilibrium and at any time t respectively. The equilibrium adsorption capacity (q\(_e\)) and the pseudo-second order rate constants (K\(_2\)) were calculated from the slope and intercept of the linear plot of t/qt against t respectively.

**Adsorption isotherms**

Adsorption isotherm studies are important in the design of adsorption process as they determine the efficiency of adsorption processes [12]. Langmuir and Freundlich isotherms were used.

**Langmuir**: The maximum adsorption capacity corresponding to complete monolayer coverage on the adsorbent surface is expressed by Langmuir isotherm shown in eqns. (4).

\[ \frac{Ce}{q_e} = \frac{K_1}{q_{max}} + \frac{1}{q_{max}} Ce \]  

Where q\(_{max}\) is the maximum adsorption at monolayer (mg/g) Ce is the equilibrium concentration of metal ion, q\(_e\) is the amount of ion adsorbed per unit weight and K\(_1\) is the Langmuir constant which is related to the affinity of binding sites (mgl\(^{-1}\)). A linear plot of Ce/q\(_e\) against Ce gives 1/q\(_{max}\) as slope and K\(_1\)/q\(_{max}\) as intercept from where the values of q\(_{max}\) and K\(_1\) will be calculated.

**Freundlich**: The Freundlich adsorption model (eqns. (5)) explains adsorption due to multilayer and heterogeneous surfaces.

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

K\(_f\) and n are called Freundlich constants and defined as relative adsorption capacity and intensity of sorption process respectively. A plot of log(q\(_e\)) Vs Ce gives logK\(_f\) as intercept and n as slope. The correlation coefficient R\(^2\) and the Freundlich parameters are also shown in tables.

**Results and Discussion**

**X-ray diffraction analysis of Al\(_2\)O\(_3\)-SDS and Al\(_2\)O\(_3\)**

The XRD patterns as indexed with the PC-APD diffraction software showed sharper peaks with fewer bauxite and silica impurities for the Al\(_2\)O\(_3\)+SDS compared to those of Al\(_2\)O\(_3\) (Figure 1). This implied that the carbonization of the SDS helped to reduce impurity phases in Al\(_2\)O\(_3\)+SDS. The estimated particle sizes were calculated as 197 and 183 nm for Al\(_2\)O\(_3\)+SDS and Al\(_2\)O\(_3\) respectively from Sherrers equation using their full width at half maximum data. Broader peaks are associated with smaller particles, which are harder for X-ray penetration, and this agreed with the results of Figure 1.

**SEM and EDS**

The surface morphologies of the Al\(_2\)O\(_3\)+SDS and Al\(_2\)O\(_3\) nanoparticles

**Figure 1**: XRD of Al\(_2\)O\(_3\)+SDS and Al\(_2\)O\(_3\) showing indexed peaks of Al\(_2\)O\(_3\) with minor impurities of silica (SiO\(_2\)) and bauxite (Al\(_2\)O\(_3\).H\(_2\)O).
analyzed using SEM are shown in Figure 2a and 2b respectively while their respective images containing the EDS data are also shown in Figure 2c and 2d. Al₂O₃+SDS (Figure 2a and 2c) appear as organized rectangular polycrystallite plates with wider pores while the Al₂O₃ (Figure 2b and 2d) reveal a rough porous thinner plate-like morphology which appear net-like in Figure 2d. The polycrystallites size variation patterns agreed with the XRD estimated values. The EDS on Figure 2c and 2d confirmed the major constituent elements of Al and O with higher percentages among common impurities of Mn, Fe, and Si also found on other samples analyzed with the same instrument. The missing O on Figure 2c was shown on a repeated spectrum but its image was blurred and so was not used.

The effect of agitation time

The calculated %R (eqns. (1)) showed a gradual increase with time from 5 min (near zero) to 90 min and a sharp increase from the 90th to its maximum of 94% at 120th min for Al₂O₃+SDS. This implied that the active adsorption sites were not saturated at 120 min. On the other hand, an undulating pattern was observed with the control (Al₂O₃) with its maximum %R at the 90th min. The significant gap (difference) between the two patterns can be linked to increase in surface area created by the presence of SDS (Figure 3a) thus achieving the desired adsorptive capacity enhancement. The importance of the shaking/agitation time comes from the need for identification of the possible rapidness of binding and removal process of the Ni²⁺ from crude oil [13].

The effect of adsorbent (Al₂O₃) and adsorbate (crude oil) concentrations

The effect of adsorbent dosage on Ni²⁺removal at different

![Figure 2: SEM of (a) Al₂O₃+SDS; (b) Al₂O₃, and their corresponding EDS (c) and (d) respectively.](image)

![Figure 3: %Removal vs. (a) Agitation time, (b) Adsorbent and (c) Adsorbate (Crude oil) concentrations.](image)
dosages of Al₂O₃+SDS (0.02, 0.04, 0.06, 0.08 and 0.1 g) showed that %R that increase gradually with increase in adsorbent from 0.02 to 0.1 g to a maximum at 86.1%. This implied that more active sites were introduced with increase in adsorbent concentration becoming more rapid towards the maximum concentration used (Figure 3b). However, there was a decline with increase in concentration of the adsorbent in the case of the control (Al₂O₃) giving maximum %R of 78% at the least (0.02 g) dosage (Figure 3b). This implied that equilibrium was reached quickly at 0.02 g such that additional adsorbent dosage crowded some of the available sites thereby reducing the adsorption capacity rather than enhancement.

Also the removal efficiency of Ni²⁺ by the adsorbents at varying adsorbate (crude oil) concentrations as investigated is shown in Figure 3c. It was observed that there was rapid decline in adsorption with increase in adsorbate (crude oil/Ni²⁺ion) concentrations with both samples (Al₂O₃+SDS) and the control (Al₂O₃) respectively. However, the former adsorbent still gapped the latter with 1%. The adsorbents active sites become quickly saturated with Ni²⁺ ions and equilibrium is reached such that additional crude oil (Ni²⁺ ion) merely increases the analyte concentration.

The effect of adsorbent (Al₂O₃) and adsorbate (crude oil) concentrations

The effect of adsorbent dosage on Ni²⁺ removal at different dosages of Al₂O₃+SDS (0.02, 0.04, 0.06, 0.08 and 0.1 g) showed that %R that increase gradually with increase in adsorbent from 0.02 to 0.1 g to a maximum at 86.1%. This implied that more active sites were introduced with increase in adsorbent concentration becoming more rapid towards the maximum concentration used (Figure 3b). However, there was a decline with increase in concentration of the adsorbent in the case of the control (Al₂O₃) giving maximum %R of 78% at the least (0.02 g) dosage (Figure 3b). This implied that equilibrium was reached quickly at 0.02 g such that additional adsorbent dosage crowded some of the available sites thereby reducing the adsorption capacity rather than enhancement.

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Adsorption kinetics

The Pseudo-first-order plot of the adsorption of Al₂O₃+SDS and Al₂O₃ plots are shown in Figure 4a and 4b respectively. The graphs showed a poor linear relationship of ln (qe-qt) against t with both processes achieving a maximum at 60 min. The non-linearity of these plots showed that a first-order mechanism was not followed in this process. The adsorption first-order mechanism for Al₂O₃+SDS showed a steady rise that climaxed at 60 with a slight decline to the 120th min while an undulating or wave-like curve was observed for Al₂O₃. However, the linearity of the second-order plots of both samples (Al₂O₃+SDS and Al₂O₃) as shown in Figure 4c and 4d confirmed that the process followed the kinetic second-order mechanism.

See higher correlation coefficient (r²) for the second-order mechanism against those of Lagergren in Table 1. This result agreed with similar reports of better fits of adsorption processes of metal ions to pseudo-2nd-order model in literature [14,15]. While the adsorption
capacity at equilibrium, \( q_e \) (mg/g) was higher for \( \text{Al}_2\text{O}_3 \) in both mechanisms; \( K_{\text{f}} \) of \( \text{Al}_2\text{O}_3+\text{SDS} \) process was better.

**Adsorption isotherm**

A plot of \( \text{Ce}/q_e \) against \( \text{Ce} \) of both samples according to the Langmuir isotherm (eqns. (4)) is shown in Figure 5a and 5b for \( \text{Al}_2\text{O}_3+\text{SDS} \) and \( \text{Al}_2\text{O}_3 \) respectively. The former showed better correlation over the latter. This means that \( \text{Al}_2\text{O}_3+\text{SDS} \) data fitted the Langmuir model better. This happens when there is more homogeneous distribution of active sites leading to complete coverage of the surface by a monolayer of adsorbate. The Langmuir model also assumes that the energies of adsorptions were uniform and independent of the surface coverage. A characteristic Langmuir isotherm dimensionless constant of separation factor (\( R_L \)) used to verify the favourability of an adsorption process by adsorbents is shown in eqns. (6) and the evaluated values in Table 2.

\[
R_L = \frac{1}{1 + K_L C_i}
\]  

(6)

where \( K_L \) is the Langmuir constant, \( C_i \) is the initial concentration of the nickel ion (Ni\(^{2+}\)). The \( R_L \) value expresses the shape of the isotherm [10]. If \( R_L \) value is 0<\( R_L <1 \), it indicates favorable adsorption, \( R_L >1 \) shows unfavorable adsorption. \( R_L =1 \) indicate linear adsorption and \( R_L =0 \) indicates irreversible adsorption isotherm respectively. The \( R_L \) values >0 obtained for both adsorbents (\( \text{Al}_2\text{O}_3+\text{SDS} \) and \( \text{Al}_2\text{O}_3 \)) confirmed favourable adsorption process. The slope of the tangent to the plot of \( \text{Ce}/q_e \) against \( \text{Ce} \) gave the \( q_{\text{max}} \) and \( K_L \) respectively (Table 2).

The equilibrium data fitted to the Freundlich isotherm (eqns. (5)) can be used to describe a non-ideal adsorption or adsorption due to multilayer or heterogeneous surfaces. Figure 5c and 5d showed the Freundlich plots for the \( \text{Al}_2\text{O}_3+\text{SDS} \) and \( \text{Al}_2\text{O}_3 \) adsorbents respectively with the constants in Table 2. The values of \( n \) for well-fitted Freundlich isotherm should lie between 1 and 10 but the values for the both adsorbents were below 1 [16]. Adsorption capacity, \( K_{f} \) of \( \text{Al}_2\text{O}_3+\text{SDS} \) was over fifty thousand times higher than that of \( \text{Al}_2\text{O}_3 \), as shown in Table 2. The lower correlation factors, \( R^2 \) compared to Langmuir suggested poorer fitting for Freundlich.

This is because Langmuir model has higher correlation coefficients of 0.95712 and 0.95258 while Freundlich, 0.8490 and 0.8079 for \( \text{Al}_2\text{O}_3+\text{SDS} \) and \( \text{Al}_2\text{O}_3 \) respectively. Also it has favourable dimensionless constant \( R_L \) indicating a monolayer adsorption process.

**Conclusion**

The sol-gel synthesis of \( \text{Al}_2\text{O}_3 \) with sodium dodecyl sulphate (\( \text{Al}_2\text{O}_3+\text{SDS} \)) and \( \text{Al}_2\text{O}_3 \) and their application in demetallization of nickel ions from crude oil-water mixtures has been reported for the first time. The XRD confirmed that both samples contained \( \text{Al}_2\text{O}_3 \) as the major phase with some minor impurities of bauxite and silica. Particle size estimations for both samples gave 197 and 183 nm respectively. This size variation was supported by the SEM micrographs that showed larger rectangular porous crystallites and thinner net-like-vertical platy crystallites for the former and later samples respectively while the EDS confirmed the presence of Al and O elements. %R of the adsorption process increase gradually with increase in adsorbent from 0.02 to 0.1 g to a maximum at 86.1% for the \( \text{Al}_2\text{O}_3+\text{SDS} \) but decrease with increase in concentration of the adsorbent in the case of the control (\( \text{Al}_2\text{O}_3 \)) with an %R maximum of 78% at the least (0.02 g) dosage. Higher removal efficiencies of 94 and 93% for a 1:3 crude oil-water mixture were also recorded for \( \text{Al}_2\text{O}_3+\text{SDS} \) and \( \text{Al}_2\text{O}_3 \) at constant adsorbate

![Figure 5](image-url)

**Table 2:** Langmuir and Freundlich isotherm parameters and correlation coefficients.
concentrations, respectively. The kinetic study confirmed that Ni\textsuperscript{2+} demetallization followed pseudo-second-order model. Demetallization of the Ni\textsuperscript{2+} by Al\textsubscript{2}O\textsubscript{3} was also favored by the presence of SDS surfactant, contact time, concentration of the synthesized Al\textsubscript{2}O\textsubscript{3} nanoparticle and the adsorbate (crude oil/Ni\textsuperscript{2+}) concentration. The adsorption isotherms showed better fits to the Langmuir model. Adsorption of (Ni\textsuperscript{2+}) by Al\textsubscript{2}O\textsubscript{3}+SDS gave higher adsorption capacity than Al\textsubscript{2}O\textsubscript{3} and its recommended for demetallization processes in the oil industry.

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