Removing Metal Ions of Cobalt (II) from Aqueous Solutions By CaO Nanoparticle

Ahmed A. Alibrahimi* and W. O. Toamah
Directorate of Education Thi-Qar, Thi-Qar, Iraq
*ahmedalibrahimi370@gmail.com

Abstract. Colloidal particles of "Calcium oxide" CaO" nanoparticles were prepared by the (sol-,gel) method from (CaCl2). The study focused on the removal of metal Co(II) from aqueous solutions by adsorption process. Powder CaO was calcination at temperature 500°C. The 9 structural (characteristics) of the synthesized sorbent were investigated, by-means of (X-ray) analysis "XRD", "FTIR spectroscopy", "transmission electron microscope" (TEM), "scanning electron microscope" (SEM) and surface area. The effect of various parameters like as the effect of pH (2, 5, 7, 8 and 10), initial concentration for metal ion Co(II) (50 – 350 mg/L) and temperature difference (5, 25, 45 and 65) °C. Almost complete removal (99 %) of metal ion Co(II) was obtained within 30 min at an optimum adsorbent dose of 0.05 mg for initial Co(II) concentration of 50 mg/L at pH = 7, room temperature (≈ 25°C) were achieved.

Keywords: Adsorption, CaO nanoparticle, Heavy metal ion Co(II), Aqueous solution.

1. Introduction

Water contaminants by many pollutants especially heavy metals which are creating major risks to public health and the environment due to their high toxicity and mobility. The "heavy metals" do not break down into nontoxic items in headwaters. They additionally gather in living bodies and getting high rate by the natural way of life [1]. Cobalt metal isn't found as a free metal and it is commonly found as minerals. Cobalt is typically not mined alone, and will in general be created as a result of nickel and copper mining exercises. The primary metals of cobalt are cobaltite, skutterudite, erythrite, and glaucodot. The world's significant makers of cobalt are the Law based Republic of the Congo, territory, Zambia, China, Australia and Russia. It is also found in Azerbaijan, Kazakhstan and Finland. World generation is 17,000 tons every year [2]. As cobalt is generally scattered in nature. Specialists in ventures that make or utilize cutting or crushing devices; mine, smelt, refine, or process cobalt metal or minerals; or that produce cobalt compounds or use cobalt can have an expanded danger of presentation [3].

As cobalt metal is present in the nature, so humans exposure can be expand by drinking water, breathing or eating food that contains cobalt metal. The contact of skin with a cobalt-containing water or floor can also increase the exposure. Cobalt in the environment is not often available, but when the cobalt ions are not bound to sediment or soil, its consumption is high by plants and animals. Thus, there may be a significant accumulation of cobalt in plants and animals. The plants grow on contaminated soil, they bank very small cobalt ions, especially in the parts of the plants we consume like fruits and seeds. Soils which may contain large amounts of cobalt are usullay near mining and melting facilities. Therefore, the consumption of plants grown on the soil by man may have some effects. The consumption of high concentrations of cobalt can be harmful and its resulting effects cause problems in respiratory such as asthma or pneumonia, vomiting, nausea, vision problems, heart problem and deterioration of the thyroid. Radioactive cobalt isotopes affect the health may be cause sterility, hair loss, vomiting, bleeding, diarrhea, coma and even death. These radiations are sometimes used in patients suffering from cancer to destroy the tumor. Cobalt has some benefits for humans, it is a component of vitamin B12, which is essential. Cobalt is used to treat anemia in pregnant women...
because it stimulates the production of red blood cells [4]. Adsorption is the method which has been used in this study. Adsorption is a mass transfer process where there is a substance transferring from the liquid phase to the surface of a solid, and is bound by chemical and/or physical interactions, the big surface area causes a high capacity of adsorption and reactivity of surface [5]. The elimination of cobalt metal ions in aqueous solution includes excellent techniques incorporates its affidavit with soluble base hydroxide alternately lime are exorbitant routines Also bring a considerable measure about hindrances for example. Adsorption is a prudent and productive procedure that can be used for the disposal of cobalt metal atoms from water samples. "Calcium oxide"(CaO) may be an exceptionally critical furthermore critical modern compound, which is used catalyst, toxic-waste medicine agent, a added substance for refractory, furthermore done paint and also for other major requisitions [6]. Ultrafine metal oxide particles might a chance to be used likewise (bactericide adsorbent). CaO has likewise demonstrated extraordinary guarantee as a ruinous adsorbent for poisonous synthetic Materials [7]. Accordingly, this examination plans should discovered a selective, basic What's more fast technique to disposal of cobalt metal ions in aqueous solutions toward utilizing CaO nanoparticle concerning a viable sorbent under those recommended states.

2. Experimental, Material and Method

2.1. Instrumental
Water-distillation pure 6 liter automatic water , which designed to provide 6 liter per hour of ultra-high purity distilled water.

pH meter (JENWAY- LTD Instrument, digital model 3310).

Spectrophotometer (Apye - Unicom UV100 -Visible Spectrophotometer).

Hotplate stirrer.

Four-Digit Analytical Balance.

Water pump.

2.2. Preparation of "Calcium oxide" CaO Nanoparticle sorbent
A proper quantity of (CaCl2) was heated to 40oC after dissolved in water. Then add "20 ml of NaOH (0.1M)" to the solution when it was being mixed quickly. After (30 minutes) reaction was heated, sifting then washing in pH value was approximately eight were completed. Thus the forerunners of CaO such as calcium hydroxide was created and left for 24 hours at 65oC ±5oC to be dried. The dried antecedents were calcined at (500 Co) for 2 hours, calcium oxide powder was formed [8, 9]. The ionic equation of the reaction is as following:

\[ 3Ca^{2+} + 6OH^- \rightarrow 3Ca(OH)_2 \downarrow \rightarrow CaO + 3H_2O \]

2.3. Stock solution of Cobalt
A standard solution of 1000 ppm Cobalt (II) was prepared by dissolution of 2.5g of CoCl2.H2O in acidified distilled water ( HCl = 2 ml), then the volumetric flask (1L) was filled up to its full mark. Standard aquatic solutions of NaOH and HCl (concentration 0.1 mg/L) were utilized for pH adjustments.

2.4. Adsorption Studies
The impact of different parameters like: effect of "pH", initial concentration for Co(II) ions (50 – 350 mg/L) and temperature different (35 and 45)oC, for each practice, (50 ml) of a sample include (Co(II) ions solution of a certain concentration "CaO sorbent" was taken in a (100 ml) measuring glass and after that blending happens with consistent air (CO2) stream rises at (250 rpm) for a required time (30 minute) to achievement adsorption evenness and to produce "calcium carbonate" consistence at 25 CO. The pH values was regulate to the required values utilizing solutions from (HCl and NaOH). After 30 minutes the examples were taken out and the solutions were isolated from the
adsorbent by separating through. The extracted percentage of cobalt ions (Extracted %) was determined by the following equation:

\[
\text{% Removal} = \frac{\text{Co} - \text{Ce}}{\text{Co}} \times 100
\]

\( \text{Co} \) is the initial liquid-phase concentrations of pollutant (mg/L).

\( \text{Ce} \) is the equilibrium liquid-phase concentrations of pollutant (mg/L).

3. Results and Discussion

3.1. Characterization of CaO Nanoparticle

3.1.1. Scanning Electron Microscope (SEM)

The SEM picture of the sorbent test was completed using a "Jeol JSM-840" under high vacuum, at an increasing speed voltage of 200 keV. And appeared in figure 1 Examining the pictures demonstrates that the incorporated size nanoparticles are under 100 nm. That implies the orchestrated sorbent has Nano measurement.

![SEM image of CaO Nanoparticle sorbent calcination at 500°C.](image)

3.1.2. Transmission Electron Microscopy (TEM)

"Transmission electron microscopy morphology" (TEM) was completed using a "JEOL 2010" instrument is appeared in figure 2 with resolving power (0.2) nm, quickening pressure being (200) kev. (TEM) image of calcium oxide nanoparticles calcination at 500°C is appeared in figure 2, which affirmed the nanoparticles of calcium oxide with a straightforward cubic structure.

![TEM image of CaO Nanoparticle sorbent calcination at 500°C.](image)
3.1.3. FT-IR Analysis

In Fig 3 the spectra of infrared of the intended CaO in the zone of 400 - 4000 cm⁻¹ are displayed. As can be seen, the readied sorbent shows assimilation groups around 2923 cm⁻¹ relating to topsy-turvy and symmetric C-H extending. Also, absorption bands at 2517 cm⁻¹ and 714 cm⁻¹ are due to carbon dioxide. Furthermore, absorption band at 1427 cm⁻¹ and 876 cm⁻¹ are due to carbonate group. At 3448 cm⁻¹ appeared a smooth band is owing to (OH) stretching of surface "hydroxyl groups", bridged adsorbed water molecules and hydroxyl groups.

![Figure 3: "IR" spectrum of CaO Nanoparticle sorbent calcination at 500oC.](image)

3.1.4. XRD Analysis

The prepared adsorbent in X-ray diffraction patterns was recorded utilizing a "Philips PW 105 diffractometer using Ni-filtered Cu Kα radiation (=1.5406 Å) at 40 keV, 30 mA", and a scanning range of 18-80°.

![Figure 4: XRD pattern of CaO Nanoparticle sorbent calcination at 500oC.](image)
3.1.5. Surface area measurement

The "surface areas" of the calcination CaO nanoparticle was computed from adsorption of nitrogen studies conducted at (-196oC). The data obtained using method involve BET method is 71.49 m²/g.

3.2. Adsorption Study

3.2.1. Effect of pH on Co²⁺ adsorption

In order to know pH effect on the adsorption of Co (II) ions, the adsorbent dosage (0.05 mg) was related with Co (II) ions (50 mg/L) at various values of pH (10, 8, 7, 5 and 2) with "30 min" contact time, as seen in (figure 5), the results appeared that the removal % is low at (pH < 7) where the concentration of H⁺ ion was high and this means that strong acidic medium, and therefore the surface of sorbent becomes high positive charged, thus lessen the centripetal force among sorbent and Co (II) particles. When increasing the (pH) values, we will notice an increase removal % and up to the most elevated an incentive at pH go (7-10) and these outcomes can be clarified as following: By with the (pH) expands "pH>5", the centralization of "H³O⁺ hydronium particle" is extremely low, the surface of the sorbent was high negative charged, along these lines the destinations are effectively accessible for Co (II) particles official. So the competition between the proton and the ion is zero or very low, and the removal % Co (II) particles is expanded at that point, at pH bend is moved to soluble area (pH>8) the removal% of Co (II) ions at most remains constant, therefore, the suitable pH of solution for maximum removal of Co (II) ions is 7.

![Figure 5: Effect of pH on adsorption capacity of Co²⁺ by CaO Nanoparticle (Conditions: Co = 50 ppm, T = 25°C; adsorbent dose = 0.050 g, V= 50 ml).](image)

3.2.2. Effect of Concentration on Co²⁺

The effect about beginning focus on the evacuation of Co²⁺ by CaO nanoparticle was examined at optimum pH = 7 and at room temperature, the results were graphed in Fig (6). When CaO nanoparticle used as an adsorbent, it showed a superior adsorption capability in ions cobalt, it has been removed within 30 min for dilute solutions at 0.05 mg adsorbent dose of CaO and initial concentration of Co²⁺ increases (5 - 350) ppm at 25 °C. The CaO demonstrated a very quick adsorption property for
the removal of Co(II) ions, more than 99%. The adsorption capability approaches 347 mg/g at concentration of Co2+ (350) ppm. The amount of Co2+ adsorbed at equilibrium removal (%) increases (95.2 - 99.14) %. So the adsorption happened on the superficies of CaCO3.

The point when "CaCO3" (sparingly dissolvable salt) may be hanging with water, CaHCO3+, Ca2+, OH-, CaHO+, HCO3- , and metal carbonate, it made Concerning illustration surface accused sorts what's more their presence could assume a part previously, watery result. Furthermore the detachment of these aggregations might prompt a basic alternately acidic surface, those molecule charges (negative) that structured through response need aid precipitation for adsorbent surface what's more secondary surface zone of 71. 49 m2/g for CaO these need aid constantly on part enormous in the adsorption for metal ions cobalt from solution.

Figure 6 : Effect of initial metal concentration on the removal of Cd2+ by CaO Nanoparticle (Conditions: Co = 50 - 350 ppm, T = 25°C; adsorbent dose = 0.050 g; V= 50 ml).

**3.2.3. Effect of Temperature on adsorption of Co2+**

Those temperature need two The greater part paramount effects on the adsorption transform. In high temperature will be basic should climb those dispersion rate of the adsorbate same time fluctuating those temperature will Different those harmony ability of the adsorbent to a particular adsorbate.

In this study, a series of tests were directed on the sorority about 50 mg/L about Co(II) ions on to 0. 05 mg from claiming CaO nanoparticles during 5, 25, 45 What's more 65°C toward pH = 7. Also blending duration of the time 30 min should examination those effect for temperature on the adsorption flow. Those outcomes portrayed for table 3 indicated that those adsorption ability climb Similarly as those temperature. Ascent underpinned that those transform will be endothermic Previously, nature.

Such effects might a chance to be credited of the structuring from claiming a few new dynamic destinations on the adsorbent alternately of the speeding up from claiming a few moderate sorption steps. Moreover, those expand from claiming versatility about Co(II) ions from those greater part about answer for those sorbent surface ought further bolstering Additionally make pay thoughtfulness regarding that. Since the vast majority fluid modern waste are by and large it spicy, those simple adsorption technique provided for here conceivably camwood use previously, mechanical wastewater taking care of to those disposal for distinctive metal ions. An increase in temperature involves an increased mobility of the metal ions and a decrease in the retarding forces acting on the diffusing ions. The increase in the sorption with the rise of temperature may be diffusion metal ion more and the metal ion is adsorbed on surface area of the adsorbent which results the metal ion
transport with in the pores of adsorbent. An increase of the adsorption capacity with increase in the temperature indicates a significant adsorption being endothermic reaction [10-12].

![Graph showing effect of temperature on adsorption capacity of Co2+ by CaO Nanoparticle](image)

Figure 7: Effect of temperature on adsorption capacity of Co2+ by CaO Nanoparticle (Conditions: Co = 350 ppm, T = (5, 25, 45 and 65)°C, adsorbent dose = 0.050 g, V= 50 ml).

4. Conclusion

According to this investigation, it could be concluded that:

• Nano-CaO that prepared can be used as an effective and inexpensive sorbent for the elimination of Co(II) from aqueous solutions.
• The process of adsorption which has features "compared to other separation methods" easy, less time consuming, being low cost, and is likely to be incorporated soon as clean wastewater and water treatment technique used in this research.
• The adsorption of Co(II) ions usually happened at the outside of the produced CaCO3 adsorbent.
• It happened of or/and "deposition" of cobalt hydroxide on the superficies of the adsorbent.

References

[1] H.S. Peavy, D.R. Rowe and G. Tehobangalos, Environmental Engineering, [2]McGraw Hill, New York, (1985) 38.

[3] https://www.lenntech.com.

[4] Texas Department of State Health Services Environmental and Injury Epidemiology & Toxicology Group.

[5] Bachir Achour Université de Biskra https://www.lenntech.com/periodic/elements /co.htm.
[6] Kurniawan, Tonni Agustiono, and Wai-hung Lo. "Removal of refractory compounds from stabilized landfill leachate using an integrated H2O2 oxidation and granular activated carbon (GAC) adsorption treatment", Water research, 43 (2009), pp: 4079-4091.

[7] B. K. Olga, L. Isabelle and V. Alexander, Alkaline-Earth Oxide Nanoparticles Obtained by Aerogel Methods. Characterization and Rational for Unexpectedly High Surface Chemical Reactivities, Chem. Mater. 9 (1997) 2468-2480.

[8] K. Olga, X. L. Yong and J. K. Kenneth, Destructive adsorption of chlorinated hydrocarbons on ultrafine (nanoscale) particles of calcium oxide, Chem. Mater. 5 (1993) 500-505.

[9] P. Lahiri and S. K. Sengupta, Spinel ferrites as catalyst: A study on catalytic effect of coprecipitated ferrites on hydrogen peroxide decomposition, J. Chem., 69 (1991) 33-36.

[10] R. K Mohammad, R A Madlol, N M Umran and F I Sharrad Structure and electronic properties of substitutionally doped cycloheptane molecule using DFT, Results Phys. 6 (2016) 1036.

[11] M. Sadeghi and M. H. Husseini, A Novel Method for the Synthesis of CaO Nanoparticle for the Decomposition of Sulfurous Pollutant, J. Appl. Chem. Res., 7 (2013) 39-49.

[12] Ju, Shao-hua, Shuai-dan Lu, Jin-hui Peng, Li-bo Zhang, C. Srinivasakannan, Sheng-hui Guo, and L. I. Wei. "Removal of cadmium from aqueous solutions using red mud granulated with cement", Transactions of Nonferrous Metals Society of China 22 (2012), pp: 3140-3146.